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FRACTURES ABOUT THE ELBOW IN CHILDREN

HAROLD B. BOYD, M.D., AND A. RALPH ALTENBERG, M.D.

MEMPHIS, TENN.

It is the purpose of this paper to discuss fractures about the elbow joint in children and to give a brief outline of the various types of fractures, their relative frequency and the method of treatment for each type.

Fractures involving the elbow joint in children are relatively common. In studying the files of the Campbell Clinic, we have found that 713 of these fractures have been treated by members of the staff in patients 12 years of age or under. These do not include the fractures treated in the service of the John Gaston (City) Hospital. Fractures involving the elbow joint in children will be discussed in the order of their frequency: supracondylar fractures, condylar fractures, fractures of the neck of the radius, Monteggia fractures, fractures of the olecranon and T-condylar fractures of the lower end of the humerus (table 1).

TABLE 1.—*Types of Fractures*

	No. of Cases	Percentage
Supracondylar fractures	465	65.4
Condylar fractures	180	25.3
Fractures of the neck of the radius	34	4.7
Monteggia fractures	16	2.2
Olecranon fractures	12	1.6
T-condylar fractures	6	0.8
Total	713	100.0

Supracondylar fractures are undoubtedly more common than these data indicate, as most of them are treated by the patient's home physician, while a large portion of the more complicated fractures, especially those requiring surgical treatment, are referred.

Damage to the nerves and blood vessels, which frequently accompanies fractures about the elbow, is often of more consequence than the fracture itself. For this reason, whether or not the nerve and the blood supply to the forearm are intact should be ascertained before reduction and observed at regular intervals during treatment. Impairment of circulation is indicated mainly by swelling, cyanosis and paresthesia or anesthesia of the hand and fingers.

Absence of the radial pulse before reduction is usually caused by pressure on the brachial artery at the site of fracture, but it may indicate trauma to the brachial artery which has resulted in thrombosis or severance of this vessel. If the radial pulse is absent owing to pressure on the brachial artery, the pulse will usually return during reduction of the fracture. If the radial pulse is present before but absent after the arm is placed in acute flexion, the amount of flexion is too great, and the elbow should be extended sufficiently to restore adequate circulation.

Examination for damage to nerves should be carried out before and after manipulation of the fracture. This is easily done, for the median, ulnar and radial nerves have functions which are readily determined. With paralysis of the median nerve the patient is unable to appose the tip of the thumb to the small finger. Paralysis of the ulnar nerve prevents "fanning" of the fingers and abduction of the small finger. With involvement of the radial nerve the patient is unable to dorsiflex the wrist or to extend the metacarpophalangeal joints. The sensory distribution in the hand of the median, ulnar and radial nerves is well known and can easily be tested. Embarrassment to the surgeon is prevented by discovering any existing injury to the nerves before rather than after the manipulation.

Volkmann's contracture is an extremely serious complication, which may follow any fracture about the elbow but which is most commonly seen after supracondylar fractures. This condition may be unavoidable and has been reported secondary to severe swelling of the soft tissues in patients who were not treated with casts, bandages or any other type of appliance. Volkmann's contracture can usually be prevented by careful observation of the circulation at regular intervals and prompt release of any constricting appliance when impairment of circulation is present.

From the Willis C. Campbell Clinic.

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SUPRACONDYLAR FRACTURES

The most common fracture about the elbow joint in children is a supracondylar fracture. The youngest patient with a supracondylar fracture in this series was 14 months of age. These fractures have occurred in all age groups up to the 12 year limit, which was set arbitrarily for this study. Table 2 indicates the incidence according to age of supracondylar fractures, condylar fractures and fractures of the neck of the radius. This table indicates that supracondylar fractures occur most frequently between the ages of 5 and 8.

A supracondylar fracture can usually be diagnosed clinically. The diagnosis should always be confirmed by roentgenographic examination, in order to determine the exact type of fracture. This is necessary to differentiate a supracondylar fracture from a condylar fracture, as the proper

TABLE 2.—*Age Incidence of Supracondylar Fractures, Condylar Fractures and Fractures of the Neck of the Radius*

Age in Years	Supracondylar Fractures (465), Percentage	Condylar Fractures (180), Percentage	Fractures of the Radial Neck (34), Percentage
1	1.37	0.66	....
2	3.21	1.32	3.45
3	6.20	3.30	3.45
4	10.10	7.24	....
5	16.15	15.12	6.90
6	14.22	11.82	6.90
7	11.45	13.81	3.45
8	14.22	8.56	10.35
9	10.10	11.83	10.35
10	4.35	9.87	24.11
11	5.05	9.87	13.80
12	4.58	6.60	17.24
	100.00	100.00	100.00

treatment of these two types of fracture is entirely different. The presence or absence of the radial pulse should be ascertained and the condition of the circulation in the hand evaluated. A careful examination should be made for damage to nerves. When impairment is present, the radial and the median nerve are most often involved. The radial nerve was involved in 2.4 per cent of the supracondylar fractures of this series and the median nerve in 1.5 per cent. The ulnar nerve was involved in 2 fractures. In 1 of these there was a combined lesion of the radial and the ulnar nerve. The neural lesion was temporary in all but 2 patients, who had involvement of the radial nerve. At operation the radial nerve was found to be severed, and it was sutured. One of these patients obtained a good result, and we were unable to trace the other. The median nerve passes in front of the lower end of the humerus between the condyles, while the radial nerve passes anterior to the lateral condyle. Either may be damaged by forward displacement of the proximal fragment. Rarely the ulnar nerve may be involved, as reported by Siris.[1]

In some supracondylar fractures the swelling of the soft tissue is too extensive to permit immediate manipulation. In such circumstances it is necessary to treat the patient with some form of traction, such as has been described by Dunlop and Hart,[2] or to place the extremity in a posterior splint until the swelling subsides sufficiently to permit manipulation. If reduction is postponed because of swelling, any pressure on the brachial artery should be relieved before the posterior splint is applied. This usually requires partial reduction of the fracture, as the swelling tends to persist and subsides slowly when wide separation of the fragments is present.

In the vast majority of cases, especially when the patient is seen within a few hours after the fracture, immediate manipulation can and should be done. We have found that, in general, the simplest and most satisfactory method of treatment is manipulation and immobilization by strapping with adhesive tape with the elbow in flexion (Jones position). The reduction is accomplished by traction on the forearm and flexion of the elbow. At the same time that this manipulation is being carried out, the distal fragment is forced forward with the thumb while posterior pressure is applied on the shaft of the humerus with the fingers of the same hand. Lateral or medial displacement of the distal fragment is usually corrected by traction on the forearm. Occasionally it is necessary to aline the distal fragment with the proximal fragment by pressure on the medial or lateral condyle. This is easily accomplished while traction is being applied to the forearm. It is difficult to correct lateral or medial displacement after the elbow is flexed. Unless the brachial artery has been thrombosed or severed, the radial pulse should be palpable after the manipulation. The forearm should not be flexed to or beyond the point of obliteration of the radial pulse. It is unwise and usually not necessary to flex the elbow beyond 45 degrees. The palm of the hand should face the sternoclavicular joint, with the humerus in slight internal rotation. The forearm should not be flexed so that it is parallel with the arm. When the former position is used the carrying angle will be preserved after extension of the elbow, while in

1. Siris, I. E.: Supracondylar Fracture of the Humerus: Analysis of 330 Cases, Surg., Gynec. & Obst. **68**:201 (Feb.) 1939.

2. Dunlop, J.: Transcondylar Fractures of the Humerus in Childhood, J. Bone & Joint Surg. **21**:59 (Jan.) 1939. Hart, V. L.: Reduction of Supracondylar Fracture in Children, Surgery **11**:23 (Jan.) 1942.

the latter position the carrying angle may be lost when the elbow is extended.

When the adhesive dressing is applied with the elbow in the flexed position, care should be taken to pad the antecubital fossa and to fill the space between the forearm and the arm with cotton. Otherwise excoriation of the skin may occur. The adhesive tape strapping should cover the entire arm and forearm from the axilla to the wrist, including the elbow. This prevents "window edema" about the elbow or between the strips of adhesive tape. It is well to wrap the wrist and hand with a gauze bandage, as this minimizes the amount of swelling in the hand (fig. 1). After this form of treatment, one can not be too careful in checking the circulation. It should be checked at least twice a day for the first three days. It is our practice to hospitalize patients with this type of fracture for twenty-four hours, so that their reaction to the anesthetic and the circulation of the extremity can be watched under optimal circumstances. If excessive swelling occurs, the patient is hospitalized for a longer period. The relatives should be instructed that if signs of impaired circulation are noted in the hand the patient should return to the doctor immediately. With this type of dressing, the adhesive tape can easily be cut and the elbow allowed to extend sufficiently to reestablish adequate circulation. As the swelling subsides, the flexion of the elbow can be gradually increased and the reduction maintained by reenforcing the strapping.

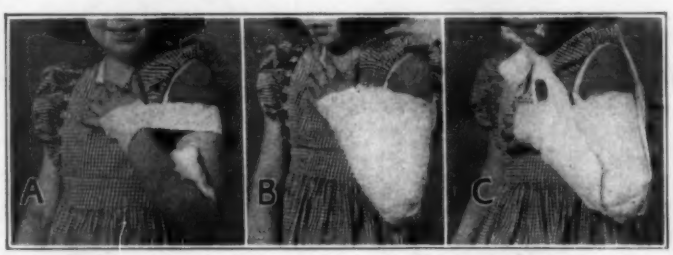

Fig. 1.—*A*, the elbow has been placed in acute flexion, slightly in excess of the usual amount. *B*, the space between the forearm and the arm has been filled with cotton and the entire area covered with adhesive tape, to prevent edema. *C*, the adhesive dressing has been covered with a gauze bandage; also the hand and the wrist have been covered, to prevent edema of the hand. The upper extremity is supported by a sling, which is fenestrated at the elbow and the wrist.

After reduction, a roentgenogram should be made to determine whether or not the reduction is satisfactory. A second roentgenogram should be taken in one week to ten days following the reduction to ascertain if any change in position of the fragments has occurred. If the fragments have slipped sufficiently to warrant remanipulation, this should be done immediately, as union occurs rapidly in children (fig. 2). The average time necessary to maintain the fixation with adhesive tape strapping is three to four weeks, at the end of which time there is usually sufficient callus to allow removal of the adhesive tape and application of a posterior splint or sling. At the end of four or five weeks, gradual active and passive motion of the elbow can be resumed. Extension of the joint should be increased slowly. It may take three to six months, and in rare cases even a longer period to obtain full extension of the elbow. Full motion of the elbow in children can usually be obtained by active motion associated with use. Physical therapy is rarely necessary for a child. Full motion might be obtained quicker by the use of physical therapy, but the time element is of no economic importance to a child. Gradually increasing active motion is safer and much cheaper than passive motion and massage carried out by a physical therapeutist. The custom of carrying weights to promote extension is not advised. The biceps and brachialis muscles contract to support the weight, thus preventing extension. If the weight could be applied constantly over a long period, it would overcome the muscular spasm and be of value. The child usually rests the biceps and brachialis muscles before the muscular spasm is overcome by fatigue. When the elbow is actively extended, the triceps muscle contracts at a time when the flexor muscles of the elbow are physiologically relaxed, thus facilitating extension of the joint.

Occasionally satisfactory reduction of a supracondylar fracture by manipulation is impossible. This is particularly true for patients with an oblique fracture in the supracondylar region, as seen in the anteroposterior roentgenogram. The oblique fracture line, ending in a thin pointed spicule of bone, forms an inclined plane, on which it is extremely difficult to engage and stabilize the fragments by manipulation alone, as there is a constant tendency for the distal fragment to slip out of position. Flexion of the elbow may increase the displacement rather than

stabilize the fragments, as is done when the fracture is transverse in the anteroposterior view. If satisfactory reduction cannot be obtained by manipulation, an open operation with internal fixation is indicated (fig. 3). In this series, 11.8 per cent of the 465 supracondylar fractures required open reduction. This percentage is higher than one would expect in unselected cases, as most of the patients were referred to the clinic after failure to secure satisfactory position of the fracture by manipulation. Forty-three per cent of the fractures requiring open reduction exhibited callus with early malunion, which prevented further manipulation. Fifty-seven per cent of those requiring open reduction were fresh fractures in which satisfactory position could not be maintained by closed manipulation.

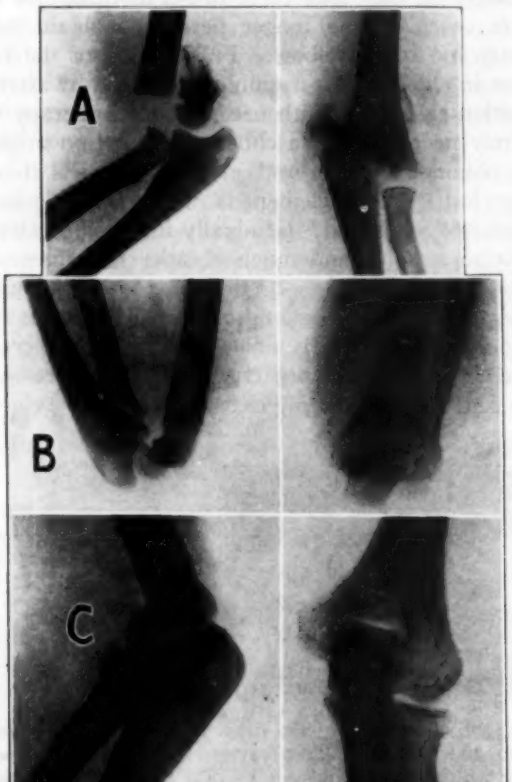

Fig. 2.—*A*, typical supracondylar fracture in a child aged 6. *B*, appearance of the fracture after closed reduction and immobilization, with the elbow in flexion. *C*, the same patient sixteen years after the fracture. Function and external contour of the elbow are normal.

Technic for Open Reduction.—The fracture is exposed through short longitudinal incisions over the medial and lateral aspects of the elbow, which expose the epicondyles and the medial and lateral borders of the humerus along the intermuscular septums. The incisions should be of appropriate length to expose the condyles of the humerus and the site of fracture. Care should be taken not to injure the ulnar nerve as it passes behind the medial condyle. With these exposures the fracture can be accurately reduced and held in position by placing a rustless steel nail through each condyle and into the shaft of the humerus (fig. 3). When the wounds are closed the ends of the nails should be covered with skin and subcutaneous tissue, but they should be allowed to protrude from the bone enough to be palpated easily beneath the skin. With this procedure the nails can usually be removed with the patient under local anesthesia.

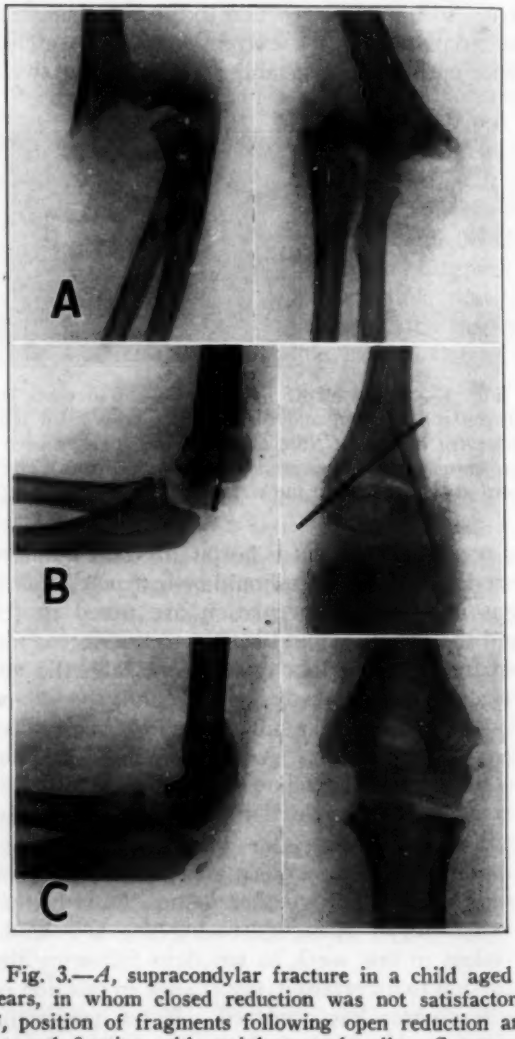

Fig. 3.—*A*, supracondylar fracture in a child aged 5 years, in whom closed reduction was not satisfactory. *B*, position of fragments following open reduction and internal fixation with stainless steel nails. *C*, appearance of bones four years after operation. The nails were removed one month following operation. End result: normal flexion and extension of the elbow joint and pronation and supination of the forearm.

Union is nearly always sufficiently solid to permit removal of the nails in six to eight weeks.

Supracondylar fractures in children are nearly always of the "extension" variety, i. e. the fracture occurs with the elbow in extension. The force is transmitted through the hand and forearm to the elbow. The supracondylar fracture results from hyperextension of the elbow. The distal fragment is forced posteriorly, and the proximal fragment protrudes anteriorly. The fracture line, as viewed in the lateral projection, may be either transverse or oblique (from posterosuperior to anteroinferior), usually the latter. Rarely (less than one-half of 1 per cent in this series) a supracondylar fracture may be of the "flexion type," which results from direct force applied to the elbow with the joint in flexion. In this event, the distal fragment is displaced anteriorly. The "flexion type" of fracture cannot be treated by flexing the forearm on the arm (Jones position), as flexion increases the displacement of the fragments. This fracture is best treated with the elbow in extension or, if necessary, by open reduction.

TABLE 3.—*Fractures of the Humeral Condyles*

	No. of Cases	Percentage
Lateral condyle	124	68.8
Medial epicondyle	33	18.3
Medial condyle	23	12.9
Total	180	100.0

Four per cent of the supracondylar fractures in this series were compound. For this type of fracture, in addition to the treatment of the fracture, adequate care of the compound wound is necessary.

FRACTURES OF THE HUMERAL CONDYLES

Fractures of the humeral condyles (180 cases) represent 25.3 per cent of the fractures of this series. Of the fractures of the humeral condyles, fracture of the external condyle is the most frequent, as demonstrated in table 3. The carrying angle predisposes to a valgus strain when force is transmitted to the condyles through the extended forearm. This probably accounts for the preponderance of fractures of the lateral condyle.

The symptoms and physical findings with a condylar fracture may be similar to those of a supracondylar fracture; however, the treatment is entirely different. The differential diagnosis should be made by roentgenographic examination. Condylar fractures of the humerus with displacement in children require open operation and internal fixation in order to obtain a satisfactory end result. Occasionally a condylar fracture without displacement occurs which does not require open reduction, but if there is displacement of a condylar fracture open reduction is indicated. The extensor muscles of the forearm have a common origin from the lateral condyle, and the flexor muscles have a common origin from the medial condyle. The muscular pull on a condylar fracture will usually redisplace the fragment, even if succesful manipulation of the fragment into position can be accomplished (fig. 4). Accurate reduction of a condylar fracture by manipulation is practically impossible, as the surgeon is unable to grasp and control the small fragment. Condylar fractures, especially those of the lateral condyle, usually show marked displacement with rotation, which may be of any amount up to 180 degrees. At operation the fragments always appear larger than the roentgenogram would lead one to expect, as the condyles in children are partially formed by cartilage, owing to lack of complete ossification. The younger the child the larger the actual size of the fragment as compared with its apparent size in the roentgenogram.

Experience has taught us that if these fractures are not accurately reduced and the reduction maintained, either malunion or nonunion of the condyle will result. With either complication there is a disturbance in growth, as these fractures pass through the centers of growth and the epiphysial lines of the lower end of the humerus. If a patient has a lateral condylar fracture which has not been properly treated, as a rule the medial condyle continues to grow while the growth of the lateral condyle is retarded, with a resultant gradually increasing cubitus valgus (increase in the carrying angle). This condition produces a progressive increase in tension on the ulnar nerve, and it is common to see a delayed palsy of the ulnar nerve in patients with this complication during adult life (fig. 5). If nonunion or malunion occurs in the medial condyle, the lateral condyle will usually grow faster than the medial condyle, with a resultant gradually increasing cubitus varus, or a loss in the carrying angle. With either cubitus valgus or cubitus varus, traumatic arthrosis is apt to occur in the elbow during adult life, owing to the irregular surface of the joint, which results from malunion or nonunion (figs. 4, 5 and 6). These complications can be prevented by an accurate early open reduction and internal fixation of the fracture (fig. 7). The operation of choice consists of a lateral longitudinal incision or a medial longitudinal incision which

exposes the involved condyle. When the site of fracture has been adequately exposed, the condyle should be anatomically reduced as one portion of a jigsaw puzzle is fitted into another. This reduction should be held by a nail or screw of either rustless steel or vitallium. Satisfactory position of the condyle cannot usually be maintained by sutures. It is difficult to suture a fractured condyle into position accurately, as there is not sufficient soft tissue to hold the sutures. If the sutures are passed through the bone the bone tends to cut surgical gut (catgut) or silk sutures, while wire sutures tend to cut through the soft bone forming the condyle. After the open reduction and the internal fixation, the standpoint, we have found that the internal fixation does not prevent normal growth of the humerus when it is removed as recommended here (fig. 7). In the patients that have had an early accurate reduction of the condylar fracture with internal fixation, normal growth in the lower end of the humerus has continued, while the patients with malunion or nonunion have shown pronounced disturbances in growth (figs. 4, 5 and 6). A condylar fracture should be operated on within the first few days following the fracture. If open reduction is delayed, fibrous tissue fills the space between the condyle and the humerus. Under these circumstances, accurate reduction of the condylar fragment is

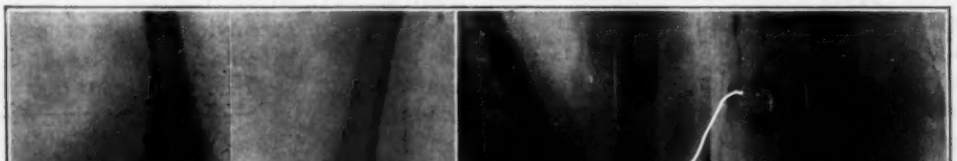

Fig. 4.—*A*, fracture of the lateral condyle of the humerus with moderate displacement in a child aged 7. *B*, position of fragments following closed reduction. This is apparently a satisfactory reduction. *C*, definite nonunion of the fracture of the lateral condyle ten months following reduction, illustrating that open reduction and internal fixation should have been employed. *D*, appearance of the fracture twelve years after reduction. The patient has a moderate increase in the carrying angle. There is crepitation on flexion and extension of the elbow. Pain is experienced with changes in weather. The patient was 19 years of age at the time of this report. As the patient grows older the pain and roughening in the elbow joint will probably increase.

arm is immobilized, with the elbow at 90 degrees or slightly flexed beyond the right angle. Union is usually sufficiently solid to permit gradually increasing active and passive motion of the elbow in approximately four weeks following the operation. It has been our practice to remove the internal fixation in six to eight weeks after the operation. This can often be done with local anesthesia.

There are theoretic disadvantages in passing a nail or screw through the growing area and the epiphysial line of the condyle. From a practical difficult, and disturbances in growth usually result. If definite malunion or nonunion is allowed to develop, the position of the condylar fragment may be improved by an operation; but the chance of securing an excellent anatomic result with continued normal growth in the lower end of the humerus has been lost. Disturbances in growth in the lower end of the humerus have developed in the patients in whom open reduction has been postponed four or more weeks following a condylar fracture. The necessity for early open reduction and internal fixation

of condylar fractures was emphasized by Speed and Macey in 1933.[3]

FRACTURES OF THE MEDIAL EPICONDYLE

The medial epicondyle is fractured more often than the medial condyle but less frequently than the lateral condyle. Usually there is an epiphysial separation of the medial epicondyle; occasionally the fracture line may pass through osseous tissue. Displacement of the epicondylar fragment may vary from a negligible amount to an actual displacement of the fragment into the elbow joint. In the latter event, there is usually an associated lateral subluxation of the elbow joint. Trauma to the ulnar nerve may be the result of pressure by the epicondylar fragment or, in cases of subluxation of the elbow, secondary to avulsion of the nerve from the ulnar groove. In the majority of cases there is definite displacement of the medial epicondyle. This displacement is maintained by the pull of the flexor muscles of the forearm through their common origin from the medial epicondyle.

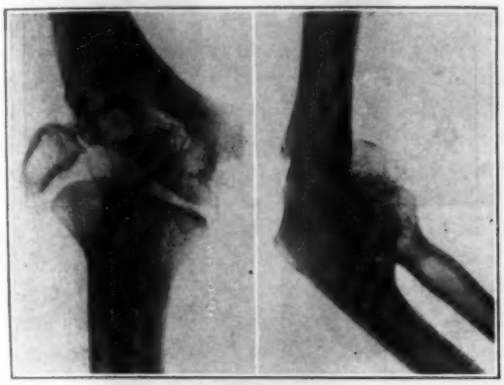

Fig. 5.—Old nonunion of a lateral condylar fracture in a patient aged 39, resulting from an injury at 9 years of age. Note nonunion of the lateral condyle, with pronounced irregularity of the elbow joint. The carrying angle is definitely increased. Symptoms referable to the ulnar nerve were first noted twenty-five years after the fracture, and there was complete paralysis of the ulnar nerve (both motor and sensory, including atrophy of intrinsic muscles of the hand) five years later, when the patient was first seen. This unfortunate end result would have been avoided by open reduction and internal fixation at the time of the original fracture.

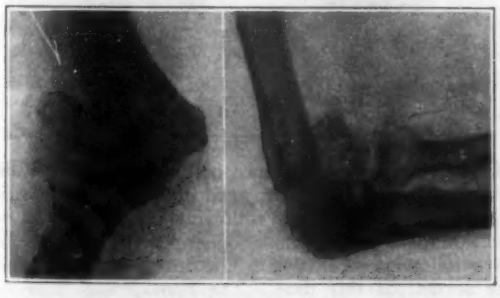

Fig. 6.—Old nonunion of a fracture of the lateral condyle in a patient 28 years of age, resulting from an injury at the age of 3. There is a distinct increase in the carrying angle, with delayed ulnar palsy. The lesion of the ulnar nerve improved after transplantation of the nerve at the elbow.

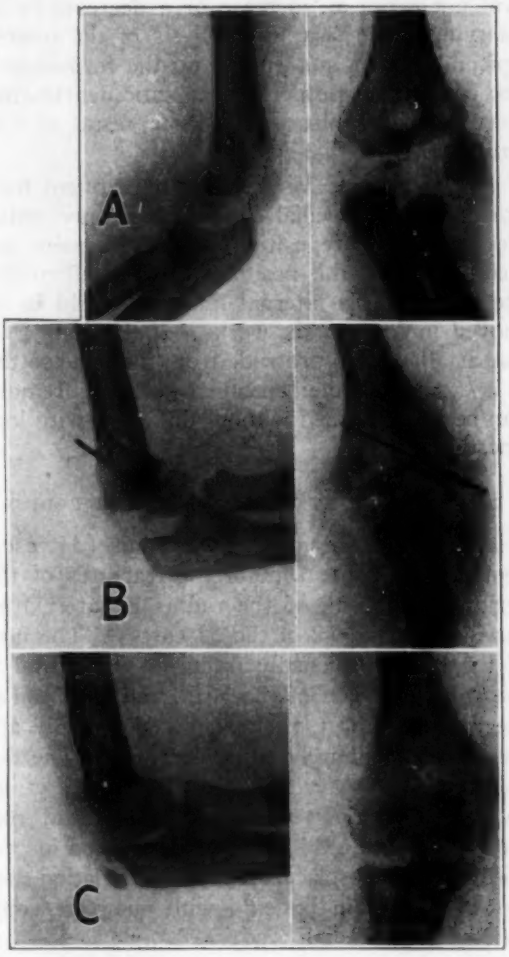

Fig. 7.—*A*, typical fracture of the lateral condyle of the humerus with rotation in a child aged 7 years. *B*, roentgenogram taken during operation, illustrating reduction of the fracture and internal fixation with a stainless steel nail. *C*, result four years after operation, showing bony union and no disturbance in growth of the lower end of the humerus. The patient had normal flexion and extension and normal pronation and supination. The external contour of the elbow and the carrying angle were normal.

Open reduction and internal fixation of the displaced epicondyle are necessary if normal development and growth in the region of the medial epicondyle are to be assured. When the epicondyle is displaced into the joint, open reduction is

3. Speed, J. S., and Macey, H. B.: Fractures of the Humeral Condyles in Children, J. Bone & Joint Surg. **15**:903 (Oct.) 1933.

necessary to remove the fragment from the joint and to reduce the subluxation. If this is not done, traumatic arthrosis of the elbow joint will develop, owing to the loose fragment in the joint and the subluxation of the elbow. In patients with moderate displacement of the epicondylar fracture, nonunion will develop if open reduction, with accurate reposition of the fragment, and internal fixation are not employed. In these patients a malformation of the internal epicondylar region will develop with growth, but this will not cause an increase or a decrease in the carrying angle, as the epiphysis of the internal epicondyle does not enter into the formation of the elbow joint proper. Traumatic neuritis may develop in the ulnar nerve as a result of nonunion of the medial epicondyle.

In the average case, the best treatment for a fracture of the medial epicondyle is open reduction, anatomic reposition of the fragment and maintenance of this position with a small rustless steel nail. This internal fixation should be removed in four to six weeks. If the end of the nail is allowed to protrude from the bone so that it is easily palpable beneath the skin, its removal can be accomplished without difficulty, with local anesthesia.

FRACTURES OF THE NECK OF THE RADIUS

Fracture of the neck of the radius (34 cases) represents 4.7 per cent of the fractures of this series. The head of the radius is rarely fractured in a child (2 of the 34 cases). The neck of the radius is usually fractured just distal to the epiphysial line of the head, and the head of the radius is most often displaced laterally and anteriorly or laterally and posteriorly. The displacement may vary from a slight amount of impaction to a complete separation of the head from the shaft. The head is usually angulated in proportion to its displacement. The angulation may be 90 degrees in patients with complete separation of the radial head.

It is difficult to change the position of the head of the radius by manipulation. If the displacement of the head of the radius is slight, no treatment other than the application of a posterior elbow splint is necessary. This splint should be used for approximately three to four weeks, after which time gradually increasing active and passive motion in the elbow may be instituted. If there is appreciable displacement of the head of the radius, open reduction is indicated (fig. 8). Removal of the head of the radius is usually the treatment of choice for an adult, but removal of the head of the radius is contraindicated for a child and should not be done. If the head of the radius of a growing child is removed, cubitus valgus will gradually occur as the forearm grows.

In the cases in which an operation is indicated, the head of the radius is exposed and the fracture reduced. The reduction may be maintained without internal fixation by slight impaction at the fracture line. In some cases internal fixation is necessary; small bone pegs, metallic nails and silk sutures have been used for the fractures in this series. When metallic nails are used they should be removed in five to six weeks.

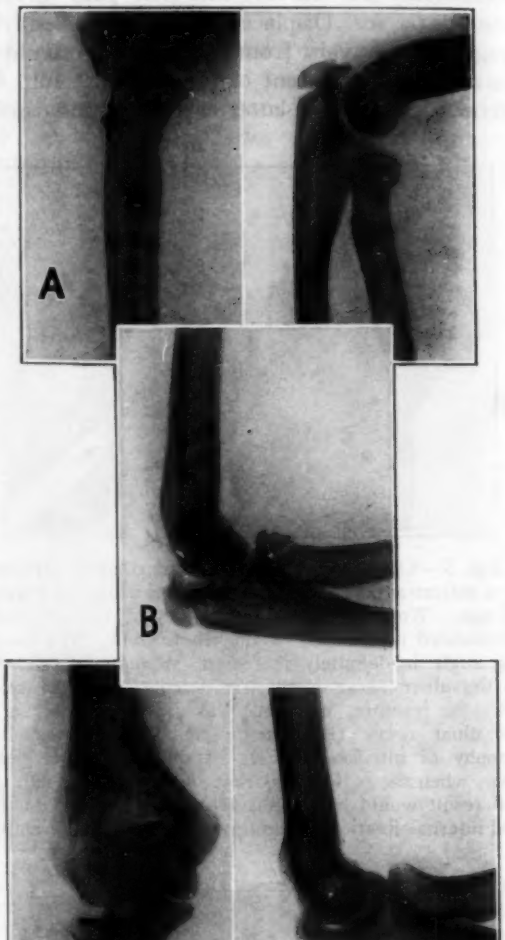

Fig. 8.—*A*, typical fracture of the neck of the radius with angulation in a child aged 10 years. *B*, position of the head of the radius following open reduction and insertion of a homogenous bone peg. *C*, result four years following operation. The function of the elbow was normal at this time. The homogenous bone peg has disappeared, and there is normal development of the head of the radius.

With the average fracture of the neck of the radius in a child, displacement is not sufficient to warrant an operation. When operation is not

warranted the end result is usually excellent. When the displacement is sufficient to warrant operation, normal function of the elbow usually results. Occasionally there may be some limitation of motion in the elbow joint, especially in pronation and supination; but as a whole the end results have been satisfactory.

MONTEGGIA FRACTURES

Fracture of the ulna with dislocation of the head of the radius (Monteggia fracture) occurred in 2.2 per cent (16 cases) of the fractures of this series. It is important in this condition not to overlook the dislocation of the head of the radius. It should be borne in mind that if there is a fracture of the ulna with overriding or distinct angulation without fracture of the radius, in all probability the head of the radius has been dislocated, as it is mechanically impossible to have any material shortening of the ulna associated with a fracture without either a fracture of the radius or a dislocation of the head of the radius. Accordingly, in all cases of fracture of the ulna a careful clinical and roentgenographic examination of the elbow joint should be made to determine whether or not the head of the radius is dislocated. For adults, the preferred treatment of fracture of the ulna with dislocation of the head of the radius is open reduction (Speed and Boyd [4]), as angulation of the ulnar fracture toward the radius invariably occurs owing to the pull of the supinator muscle on the proximal fragment. Unless internal fixation is applied to prevent this angulation, some permanent limitation of pronation and supination is the rule. In children the ulna angulates toward the radius, the same as it does in adults, but the major portion of this angulation may be corrected by growth (fig. 9). This is particularly true for young children, as the amount of correction that can be expected is directly proportionate to the subsequent growth. The important factor for a child is an accurate reduction of the dislocation of the head of the radius and maintenance of this reduction. This can usually be obtained by manual reduction of the dislocated head followed by immobilization of the forearm in a position halfway between full flexion and 90 degrees of extension. Usually the fracture of the ulna will be sufficiently united at the end of six weeks to allow gradual extension of the elbow. If the head of the radius redislocates after extension of the elbow, an operation should be done and a fascial loop placed about the neck of the radius to prevent further redislocation. In a fresh fracture, if the head of the radius cannot be successfully reduced by closed manipulation, an open reduction of the dislocation of the head of the radius with substitution of the annular ligament by a fascial loop or suturing of the torn annular ligament should be carried out in a child as in an adult. If open reduction is necessary to reduce the dislocation of the head of the radius, internal fixation should usually be applied to the fracture of the ulna at the same time.

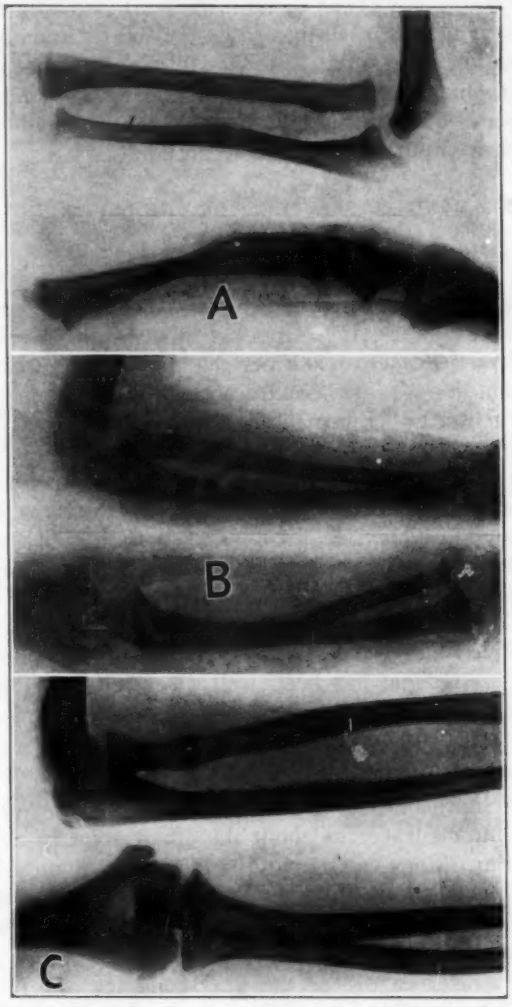

Fig. 9.—*A*, fracture of the ulna with dislocation of the head of the radius in a child aged 2½. *B*, roentgenogram taken three weeks following closed reduction. The head of the radius is in its normal position, but the ulna has united with definite angulation at the site of fracture. *C*, result twelve years following the fracture. The angulation of the ulna has been nearly corrected by growth, and the patient has normal contour and function of the elbow, including pronation and supination. In older children this amount of ulnar deviation would not be corrected by growth.

4. Speed, J. S., and Boyd, H. B.: Treatment of Fractures of the Ulna with Dislocation of the Head of the Radius (Monteggia Fracture), J. A. M. A. **115**: 1699 (Nov. 16) 1940.

FRACTURES OF THE OLECRANON

Fracture of the olecranon in children is relatively rare (12 cases, or 1.6 per cent of the fractures in this series). Occasionally a fracture occurs through the epiphysis of the olecranon and does not require any treatment other than immobilization in a splint. A fracture of the olecranon may occur without material displacement, in which case it can also be treated by immobilization in a splint. If wide displacement of the fragments occurs, open reduction with wiring or some other form of internal fixation should be carried out in a child as in an adult.

COMMINUTED FRACTURES OF THE LOWER END OF THE HUMERUS

Comminuted fracture of the lower end of the humerus (T-condylar fracture) is the least common fracture involving the elbow joint in children (6 cases, or 0.8 per cent of the fractures in this series). These fractures require open reduction and internal fixation to reconstruct the articular surface of the lower end of the humerus. We have employed the same operative principles for children with this condition as for adults. The fragments are most readily assembled and the internal fixation applied through a posterior incision similar to that used by Campbell [5] for arthroplasty and described by Speed [6] for old posterior dislocation of the elbow. This technic has been well described and illustrated by Van Gorder.[7]

CONCLUSIONS

Supracondylar fractures are by far the most common fractures about the elbow joint in children. They can usually be treated by manipulation. Special care should be taken to prevent Volkmann's contracture following these fractures.

Fractures of the humeral condyles are relatively common in children, and an accurate differential diagnosis between this lesion and a supracondylar fracture should be made by roentgenographic examination. Condylar fractures should be treated by immediate open reduction and internal fixation, to prevent subsequent deformity and traumatic arthrosis of the elbow joint. These complications are seen in adult life, as a result of disturbance in growth following an ununited or malunited condylar fracture.

Fractures of the neck of the radius occurring in children should be treated by conservative or operative means, depending on the amount of displacement present. The head and neck of the radius should not be removed in a growing child.

With fractures of the ulna, careful clinical and roentgenographic examination of the elbow should be carried out to determine whether or not a dislocation of the head of the radius is present, and if present adequate treatment should be instituted.

Fractures of the olecranon are rare in children; when they occur with displacement, open reduction and internal fixation are usually indicated.

Comminuted fractures of the lower end of the humerus require open reduction and internal fixation to restore the anatomic alinement of the articular surface of the lower end of the humerus.

5. Campbell, W. C.: Arthroplasty of the Elbow, Ann. Surg. **76**:615 (Nov.) 1922.

6. Speed, J. S.: An Operation for Unreduced Posterior Dislocation of the Elbow, South. M. J. **18**:193 (March) 1925.

7. Van Gorder, G. W.: Surgical Approach in Supracondylar "T" Fractures of the Humerus Requiring Open Reduction, J. Bone & Joint Surg. **22**:278 (April) 1940.

ABSTRACT OF DISCUSSION

DR. JOHN DUNLOP, Pasadena, Calif.: I shall confine my remarks to two types of fracture: (1) separation of the median epicondyle of the humerus and its complications; (2) transcondylar fracture of the humerus. In the first type, the mechanism of the fracture should be known to fully understand its many ramifications. For instance, a stress is placed on the median epicondyle while it is still a separate epiphysis, not having developed sufficiently to have become joined firmly to the shaft of the humerus. When this force is sufficient, owing to the pull of the flexor muscles of the forearm the medial epicondyle breaks away at the epiphysial line, and with the contraction of this muscle group it is drawn distally, and there is an accompanying tear of all the soft supporting tissues of the medial side of the elbow. With the loss of these supporting tissues, the elbow joint opens on the medial side, much as a book is opened. When this happens, the median epicondyle may fall into the elbow joint and it may become caught there. If now the surgeon attempts to reduce what he judges to be a dislocation or a partialy reduced dislocation, he may grind this mass (the median epicondyle) into the surface structures of the condyle of the humerus or into the olecranon process, causing irreparable damage. If the force which separates the medial side of the joint is sufficient and the lateral structures of the elbow joint hold, a fracture of the head of the radius may occur. Also the lateral condyle of the humerus may become fractured from the same application of force, which may produce a fracture of the head of the radius. If the application of force continues it is possible for the soft supporting tissues on the lateral side of the joint to give way, with a complete lateral dislocation of the forearm on the humerus. This is depicted in my article "Elbow Injuries," *American Journal of Surgery*, February 1939. The repair of simple epicondylar separations is easy. The epicondyle with its muscular attachments should be found and fixed in position. The ulnar nerve should

always be located and retracted during this operation. Temporary metal fixation has been found satisfactory. Fractures of the head of the radius or lateral condyle must of course be cared for if present.

Of even more interest to me are transcondylar fractures, fractures of the lower end of the humeral metaphysis which pass through the olecranon fossa. I first treated such fractures by lateral traction in 1927, because I had found that reduction was difficult by manipulation and even more difficult to hold after reduction. Reduction must be maintained in order to preserve the olecranon fossa, for if this space becomes filled by bony tissue or bony repair tissue, full extension or even full flexion may be impossible, owing to a bony block.

By traction reduction may be obtained, and if the traction is maintained until there is sufficient callus a functioning elbow joint will almost certainly result. Open reduction of this fracture should be condemned as an absolutely unnecessary procedure if the traction method of reduction is understood. The great majority of permanently flexed elbows are due to poor results from this fracture, and in my experience this method of handling them has been highly satisfactory. I have never seen a permanently flexed elbow following this method of treatment. The diagnosis of a transcondylar fracture can always be made from the roentgenogram by the fish tail appearance of the distal end of the proximal fragment, and when this is seen the fracture immediately calls for this type of treatment. It has been suggested that traction for reduction prevents Volkmann's ischemic paralysis. Traction should be applied immediately on the appearance of the first symptoms of impaired circulation.

Dr. J. Warren White, Greenville, S. C.: My remarks are going to be applied particularly to supracondylar fractures. I think, however, that an unnecessarily fine distinction is made between the supracondylar and the transcondylar type. It is true that with transcondylar fractures gross deformities are more likely to develop later. Either I have been lucky or there have not been many cases in which late deformities have occurred. Late deformities of the elbow in my part of the country are not common, although I do see more fractures of an elbow than any other injury of bone. As the men in western South Carolina seem to be afraid of fractures of the elbow, I treat many of them as well as fractured femurs, but not so many of the other types of fracture.

I should like to describe one device for immobilizing elbows, which I have been using for many years and which holds the elbow in acute flexion satisfactorily, allowing me to keep watch of the elbow and the circulation in the hand efficiently. This is a simple, standard triangular sling. The elbow is in acute flexion. The diagonal of the sling goes around the hand, one corner comes under the axilla of the affected arm and the other comes up over the shoulder of the other arm. They are pinned together, not tied, usually with a supplementary neck pad, for comfort. The right angle corner below the affected elbow comes up under the arm, and four thicknesses of the sling are pinned together: the two tails, the diagonal and the corner. One pin holds practically the whole arrangement, but other pins at strategic points are desirable. In the first week after reduction, in addition I put a 2 inch (5 cm.) strip of adhesive tape around the whole sling and around the body, including of course the upper part of the affected arm. It can be lowered or raised and it is a good deal more easily adjusted than the adhesive tape to which Dr. Boyd referred. Of course it is far easier to take off. The arrangement can be easily adjusted every day, cleansing is facilitated, and the patient can be kept comfortable. The use of the sling facilitates the taking of roentgenograms—another advantage of this simple dressing. Frequently when lateral roentgenograms are being taken the arm is rotated out so that a deformity is produced, which is not there if the elbow has not been strained. I am sure that many have noted that particular point.

I have not had the difficulty Dr. Dunlop has mentioned, and I do not know when I have done an open reduction. This sling is most useful for caring for these frequent injuries.

Dr. Walter Blount, Milwaukee: I cannot emphasize too frequently that fractures in children are different. I am gratified to note that Dr. Boyd's paper and the discussion have backed up this contention. I have developed another maxim which is particularly applicable to fractures of the elbow: "The hard ones look easy, and the easy ones look hard." As an example, the supracondylar fracture, which often fills the practitioner with terror, is relatively easy to treat by the methods just outlined. Fracture of the lateral condyle, on the other hand, is frequently missed and called a sprain because of the minimal deformity, when treatment by open reduction is really indicated.

I should like to emphasize two points particularly. The first concerns the accuracy of reduction that is necessary. At the elbow, as elsewhere in children, alinement is of great importance, apposition of less. Proper alinement includes correction of rotational and angular deformities. Dr. Dunlop's method accomplishes this well. At the Milwaukee Children's Hospital it is used routinely when a patient comes in nine or ten hours after the fracture with a large amount of swelling. After the swelling has been reduced, the elbow is frequently manipulated under anesthesia in the interest of obtaining more perfect position.

I should like to endorse the use of Dr. Dunlop's method of traction in cases of threatened Volkmann's ischemic contracture. It may well be combined with hot compresses, with relief of the symptoms in most cases. Operation should, of course, be carried out if the symptoms are not relieved.

In 1 case an ordinary transcondylar fracture was reduced by manipulation with the elbow under anesthesia. Perfect position was obtained. Symptoms of ischemia appeared, and the arm was kept in lateral traction for three weeks before the threat to the circulation disappeared. By this time, union had occurred, with rather distinct posterior displacement of the distal fragment but normal alinement. The distal end of the proximal fragment protruded as a block to flexion. Judgment to leave the fracture in this position was vindicated by the appearance of the fracture seven months later and again two years after the injury. At the latter date, motions of the elbow were normal and symmetric with the other side. The protruding angular fragment of bone had completely disappeared.

Similarly, a bony block in the olecranon fossa will disappear with time. I do not share Dr. Dunlop's concern over this temporary complication. Errors in alinement of rotation or angulation are usually permanent.

Dr. Boyd did not have time during his presentation to emphasize a fundamental rule, "Never take out the radial head of a child." The fracture usually occurs through the neck rather than the head of the bone. If there is only slight displacement, the deformity can be left as it is. If the displacement is severe, open reduction will probably be necessary. The fragments can be brought into good position and maintained by acute flexion of the elbow. Internal fixation is not necessary. The important thing is not to remove the head as one would for an adult. Fractures in children are different.

DR. HAROLD B. BOYD, Memphis, Tenn. (closing): The excellent discussion of this paper is appreciated, and I wish to thank the discussers.

Dr. Dunlop has emphasized the importance of transcondylar fractures. In my series the majority of patients with transverse transcondylar fractures were treated successfully in the Jones position. Oblique transcondylar fractures were difficult to reduce and accounted for most of the open reductions.

Dr. White has described an interesting type of dressing for supracondylar fractures.

Dr. Blount has emphasized the importance of not removing the head of the radius in a child. He also stated that accurate anatomic reduction is not as necessary for children as for adults. This is true when the fracture involves the shaft of the humerus, but this principle does not hold for fractures of the humeral condyles, as those fractures must be accurately reduced to prevent disturbances in growth and the resulting deformity.

EFFECT OF TOPICAL APPLICATION OF VITAMINS AND SOME OTHER CHEMICALS ON THE HEALING OF WOUNDS

ROBERT H. WILLIAMS, M.D., AND GROSVENOR W. BISSELL, M.D.
BOSTON

Many studies have been reported of the effect of various substances in promoting the healing of wounds. Most of these investigations have dealt with antibacterial drugs, but some have dealt with dietary measures which tend to improve the condition of the subject as a whole and in turn increase the rate of healing of wounds.[1] Deficiency in the body of proteins,[2] vitamins A and D [1a] and vitamins C [3] impairs the rate of healing of wounds.

A number of local factors influence healing. Messer and McClellan [4] found that wounds benefited more from an alkaline p_H than from an acid one. Several investigators [5] reported that the local application of concentrated urea is of distinct aid in promoting healing of wounds, particularly for removing debris and necrotic tissues. However, this therapy is often associated with marked discomfort. Compounds containing the sulfhydryl radical [6] stimulate growth of tissue, but their application has frequently been associated with pain and a disagreeable odor. There have been many observations [1a] of the effects on the healing of wounds of the local application of vitamin A, vitamin D and cod liver oil. In general, these substances have been found to stimulate granulation and epithelization.

In view of the general growth-promoting properties of the vitamins we have studied the effects of essentially all of these substances when applied directly to wounds. In this investigation we were interested in increasing the rate of healing in normal rats. The animals used were of the Wistar strain. They had been fed fox chow, carrots and celery leaves for several weeks before the beginning of the experiment. The majority had also been given cod liver oil and brewers' yeast occasionally, but they received neither of these substances for about one month before the study was started.

METHODS OF STUDY

The experiments were conducted with four groups of rats. There were some differences in the conditions of the experiments for each group.

EXPERIMENT 1.—There were 45 male rats in this group, most of which weighed from 250 to 300 Gm. The hair over the dorsal portion of the chest was shaved and the skin scrubbed with 70 per cent alcohol. While the animal was under ether anesthesia a scalpel was used to produce three lesions in the dorsal paravertebral region of each rat. On the left side an elliptic area of skin, 1.3 by 0.5 cm., was excised, the incision extending into but not through the corium. About 2 cm. away from this lesion another one of about equal size, but extending into the subcutaneous layer, was produced. On the right side, in an area about 1.3 cm. square, essentially all of the tissue outside of the thoracic cage was excised. Of the 45 animals so prepared, 6 received no treatment, while the remaining 39 were divided into groups of 3 and were treated with one of the following substances: [7] vitamin A,

From the Thorndike Memorial Laboratory, Second and Fourth Medical Services (Harvard), Boston City Hospital, and the Department of Medicine, Harvard Medical School.

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2. Thompson, W. D.; Ravdin, I. S., and Frank, I. L.: Effect of Hypoproteinemia on Wound Disruption, Arch. Surg. **36**:500-508 (March) 1938. Whipple, A. D.: The Critical Latent or Lag Period in the Healing of Wounds, Ann. Surg. **112**:481-488, 1940.

3. Holman, E.: Vitamin and Protein Factors in Pre-Operative and Postoperative Care of the Surgical Patient, Surg., Gynec. & Obst. **70**:261-269, 1940. Lanman, T. H., and Ingalls, T. H.: Vitamin C Deficiency and Wound Healing: An Experimental and Clinical Study, Ann. Surg. **105**:616-625, 1937. Hunt, A. H.: The Role of Vitamin C in Wound Healing, Brit. J. Surg. **28**:436-461, 1941. Lund, C. C., and Crandon, J. H.: Ascorbic Acid and Human Wound Healing, Ann. Surg. **114**:776-790, 1941.

4. Messer, F. C., and McClellan, R. H.: Surgical Maggots: A Study of Their Function in Wound Healing, J. Lab. & Clin. Med. **20**:1219-1226, 1935.

5. Robinson, W.: Use of Urea to Stimulate Healing in Chronic Purulent Wounds, Am. J. Surg. **33**:192-197, 1936. Holder, H. G., and MacKay, E. M.: The Use of Urea in the Treatment of Infected Wounds, J. A. M. A. **108**:1167-1169 (April 3) 1937.

6. Reimann, S. P., and Hammett, F. S.: Cell Proliferation Response to Sulfydryl in Man, Proc. Soc. Exper. Biol. & Med. **27**:20-22, 1929. Riley, J. F.: Sulphydryl Compounds and Wound Repair, Brit. M. J. **2**:516-519, 1940.

7. The preparation of vitamin A, supplied by Winthrop Chemical Company, New York, contained 65,000 U. S. P. units of natural vitamin A per gram. The vitamin E was also supplied by Winthrop Chemical Company, in spherical capsules with a volume of ap-

(Footnote continued on next page)

thiamine hydrochloride, nicotinic acid, riboflavin, calcium pantothenate, pyridoxine, biotin, vitamin C, vitamin D, crude liver extract, a vitamin mixture or sesame oil. All of the water-soluble vitamins used were suspended in sesame oil, to delay the absorption of these substances and thereby prolong their exposure to the margins of the wounds. About 8 cc. of sesame oil was placed in a series of sterile glass vials. To each, one of the following substances was added: 100 mg. of thiamine hydrochloride, 100 mg. of pyridoxine, 30 mg. of the methyl ester of biotin, 100 mg. of calcium pantothenate, 100 mg. of vitamin C, 20 mg. of riboflavin, 100 mg. of nicotinic acid or 100 mg. of liver extract. Each of the fat-soluble vitamins was mixed with an equal volume of sesame oil. The vials were shaken well, and a small amount of solution was taken from each one and mixed together to form what we called the "vitamin mixture." Two drops of one solution was placed on each wound and gently massaged. Sterile rubberized silk, which had been sewed to a gauze bandage, was placed directly in contact with the wound. One end of the bandage was anchored to the skin at a point distant from the wound. The animals treated with liver extract, pyridoxine and the "vitamin mixture" were caged singly to avoid the ingestion of the applied material by another rat. The remainder of the animals were caged in groups of 3, according to the type of treatment. A new supply of vitamins was applied daily, at which time the degree of healing of the wounds was carefully noted. A biopsy of the superficial lesion was made after four days, of the deeper lesion after twelve days and of the deepest lesion after sixteen days. Sections were made uniformly through the center of the lesion. The tissues were fixed in Zenker's solution and stained with eosin and methylthionine chloride (methylene blue). The sections were studied particularly from the point of view of extent of epithelization, mitosis, thickness of fibrous layer, vascularization, evidence of necrosis and evidence of infection. However, none of the substances exerted a beneficial effect.

EXPERIMENT 2.—A somewhat similar experiment was conducted with another group of rats. There were 48 female rats in the group, and they were essentially the same size as the animals in experiment 1. From each dorsal paravertebral region of these animals was excised an area of tissue about 1.3 cm. square, including all of the structures external to the thoracic cage. Six of the animals remained untreated, but the remaining 42 were divided into groups of 3 and were treated with each of the substances [8] used in experiment 1 and also with cod liver oil. Each animal treated with the latter was kept in a separate cage. Two drops of each solution was applied daily to each wound. No bandages were used in this group. Four days after the wounds were produced we began injecting 0.05 cc. of a set of solutions which were of the same concentration as the ones applied topically. The injections were made into the subcutaneous tissue just beneath each of two edges of the wound. The lesion on the left side was totally excised for study after ten days of treatment, and the one on the right was excised after seventeen days. The sections were prepared and studied in the manner outlined in experiment 1. There was no evidence that any of the substances had exerted an advantageous effect on the healing process. However, at the sites of the injections sterile abscesses had formed. We believed that these reactions could be attributed to sesame oil, but we investigated them further, as well as the effects of several other oils and gums, in the hopes of obtaining a vehicle which would delay the absorption of the vitamins but would not cause an inflammatory reaction.

EXPERIMENT 3.—The solutions tested were peanut oil, olive oil, cotton seed oil, liquid petrolatum, sesame oil, oleic acid, glycerin, hydrosorb [9] and two preparations of acacia. The hydrosorb was prepared as a thin paste with water. The two preparations of acacia were prepared as 5 per cent aqueous solutions. All solutions were sterilized. Daily injections of 0.1 and 1 cc. were made into the subcutaneous tissues of rats, with an attempt to observe sterile technic. Each substance was injected at six sites, and biopsies of these sites were made after two, four and six days respectively. The tissue was fixed in Zenker's solution, and the sections were stained with eosin and methylthionine chloride (methylene blue). An inflammatory reaction was observed in each of the biopsy specimens. An acute necrotic reaction with the formation of sterile abscesses was observed in the wounds treated with hydrosorb, oleic acid and one preparation of acacia. A moderate inflammatory reaction occurred at the sites of injection of peanut oil, liquid petrolatum and the other preparations of acacia. The reactions to cotton seed oil, sesame oil, olive oil and glycerin were relatively mild. However, even with these there were cystic changes, with the formation of thin fibrous walls and a surrounding area of lymphocytes, macrophages, plasma cells and a few polymorphonuclear cells.

EXPERIMENT 4.—In view of the reactions to oils and gums, we undertook another experiment in which we avoided the use of sesame oil as a vehicle. Furthermore, in this experiment we attempted to make all of the wounds of exactly the same size by using a hole punch. With this process practically no bleeding resulted, and the wounds appeared clean. In this experiment the water soluble vitamins were used in essentially the same dilution as in experiments 1 and 2, but water was used as the diluent instead of sesame oil. The fat-soluble vitamins were not diluted. This experiment also differed from the others in that no cod liver oil, liver extract or "vitamin mixture" was used but a few

proximately 0.2 cc., each containing 50 mg. of mixed tocopherols equivalent to 30 mg. of alpha tocopherol. The vitamin D (crystalline vitamin D_3) was supplied by Winthrop Chemical Company, in capsules slightly larger than those containing vitamin E; each capsule contained 50,000 U. S. P. units of vitamin D_3 in sesame oil. The riboflavin was furnished in crystalline form by Winthrop Chemical Company. The thiamine hydrochloride, calcium pantothenate, vitamin C and nicotinic acid were supplied in crystalline form by Merck & Co., Inc., Rahway, N. J. The methyl ester of crystalline biotin was furnished by the S. M. A. Corporation, Chagrin Falls, Ohio. The liver extract was Wilson's crude product no. 343.

8. The biotin used in this experiment was biotin concentrate (no. 5,000). It contained 200 gammas of biotin per 1 cc. and was supplied by the S. M. A. Corporation.

9. One acacia solution and the hydrosorb were supplied by Abbott Laboratories, North Chicago. Hydrosorb is said to be a water-absorbent ointment base consisting of a mixture of oleic acid ester and amide of diethanolamine, oleic acid and white petrolatum. The other acacia was in a white granular form supplied by Arthur H. Thomas Co., Philadelphia..

additional substances were tried. Amino acids[10] and adenosine were used because of their ability to stimulate the growth of yeast.[11] The amino acids were not diluted, but the adenosine was used in quantities of 20 mg. per 10 cc. of water. We also tested the effect of hydrosulphosol, biodyne and urea and sulfathiazole ointment. Hydrosulphosol was diluted 1:4 with water, and the other two substances were used just as they were. There were 67 rats in this group. Most of them were males weighing about 300 Gm. After shaving the hair from the entire back, we placed three round holes 1.5 cm. in diameter through the skin on each side of the vertebral column. No treatment was applied to any of the wounds on the right side. To the lesions on the left was applied one of the vitamins used in experiment 1 or 2 or hydrosulphosol, biodyne, urea and sulfathiazole ointment, amino acids, adenosine or sulfamerazine. These substances were applied to each of the three lesions on the left. At least 3 rats were treated with each chemical. There were 4 rats treated with hydrosulphosol, 8 treated with biodyne and 3 treated with sulfamerazine alone. Nine animals had no treatment. One of the 3 animals in each group was treated with sulfamerazine as well as one of the other substances. With this arrangement we could evaluate the effect of the vitamins or the other substances when they were associated with the local or general effects of sulfamerazine and could compare these changes with the ones occurring in the total absence of this drug.

The p_H of Wounds After the Application of Various Chemicals

Chemicals Used	p_H of Chemicals	p_H Three Min. After Application	
		Wound 1	Wound 2
Thiamine hydrochloride	3.3	7.6	7.6
Nicotinic acid	3.5	7.2	7.4
Calcium pantothenate	6.2	7.2	8.0
Pyridoxine	3.0	6.3	6.3
Biotin	6.3	6.5	6.7
Riboflavin	8.4	8.2	8.1
Vitamin C	6.8	7.2	7.3
Hydrosulphosol	9.5	7.9	8.1
Adenosine	6.8	7.9	8.0
Amino acid	3.5	6.1	6.3
Sulfamerazine	8.5	7.8	7.9
		7.6	7.8
Untreated	...	8.0	8.0
		7.9	7.9

The p_H of the chemicals was determined before and after they were applied to some of the wounds (table 1). The p_H of the wound after application of the various substances ranged from 6.1 to 8.2.

After the wounds had become 3 days old daily injections of 0.025 cc. of the test substance were made subcutaneously at the rostral and caudal margins.

The general appearance of the wounds was observed carefully each day. On the sixth day measurements were made of the diameter of the lesions. Although the lesions treated with calcium pantothenate were slightly narrower than the others, there was no remarkable difference.

After therapy had been administered for ten days the animals were killed, and the most caudal lesion on the left side of each rat was excised and fixed in Zenker's solution for the preparation of microscopic sections. The other 5 wounds were excised in such a manner that the lateral and the medial margins of the lesions were barely eliminated. The tensile strength of the wound was then tested by clamping a hemostat to each end of the skin; one hemostat was suspended from a fixed hook, and the other was attached to a graduated container. Water was then poured into the container until the wound broke. There was no striking difference in the tensile strength of the various lesions. The ones treated with nicotinic acid and thiamine hydrochloride were slightly stronger than the remainder.

The microscopic sections were studied in the manner described in experiment 1. None of the substances used exerted a definite healing effect. In fact, several substances apparently retarded healing.

SUMMARY

A study was made of the effects of many substances on the acceleration of the healing of wounds when applied topically to uniform-sized wounds in normal rats. The substances studied were vitamins A, C, D and E, thiamine hydrochloride, nicotinic acid, riboflavin, calcium pantothenate, pyridoxine, biotin, hydrosulphosol, biodyne, urea-sulfathiazole ointment, amino acids, adenosine, liver extract, cod liver oil, a "vitamin mixture" and sesame oil. The effect of sulfamerazine used in conjunction with most of these substances was also observed. No definite benefit was derived from the use of any of these substances, as judged by frequent observations of the wounds, their strength and the microscopic changes.

10. The amino acids (parenamine) were supplied by Frederick Stearns & Company, Detroit. The sulfathiazole and urea ointment was supplied by the Winthrop Chemical Company; it contained 5 per cent sulfathiazole and 30 per cent urea in a fat-soluble base. The adenosine was furnished by Dr. Fritz Lippmann of the Harvard Medical School. The hydrosulphosol was supplied by the Cottie-Wilson Laboratories, Los Angeles. This solution is stated to contain sulfhydryl linkage pentathionate (ion) in compounds of polysulfides and thiosulfates in water. The biodyne ointment was furnished by Sperti, Incorporated, Cincinnati. This ointment is said to consist of live yeast cell derivative (1 per cent), nonsaponifiable liver oil (3 per cent) and phenylmercuric nitrate 1:20,000 in a specifically adapted liquid petrolatum–petrolatum base. The sulfamerazine was in a 2 per cent solution in the form of its sodium salt.

11. Loofbourow, J. R.: Role of Adenine Nucleotides and Growth Factors in Increased Proliferation Following Damage to Cells, Nature, London **150**:349-350, 1942.

TRIPHALANGEAL BIFID THUMB

REPORT OF SIX CASES

PAUL W. LAPIDUS, M.D.
NEW YORK
AND
LIEUTENANT COLONEL FRANK P. GUIDOTTI
MEDICAL CORPS, ARMY OF THE UNITED STATES

In a previous communication on a study of 6 cases of triphalangeal thumb, we [1] postulated that triphalangism of the thumb should be regarded as incomplete development of one of the phalanges of the bifid thumb. According to this theory, "the additional phalanx of the triphalangeal thumb is not a true middle phalanx similar to that of the lesser fingers, but a remnant of the base of one of the phalanges of a bifid thumb."

Six cases of triphalangeal thumb associated with bifid thumb in the same person were observed subsequent to our first communication [1] and furnish supporting evidence for this theory. Six additional cases, found in the course of examination of draftees at the New York Recruiting and Induction Station, are presented here.

REPORT OF CASES

CASE 1.—A Negro truckman, aged 27 years and a native of Georgia, was a well built, normal person except for his thumbs. His history revealed that his mother had long "bent thumbs" like his, and a maternal male cousin also had one deformed thumb.

On examination, both thumbs (fig. 1 *A*) were found to be triphalangeal and unusually long, especially the left, the tip of which reached to the level of the proximal interphalangeal joint of the index finger.

From the history it was learned that the left thumb had originally been bifid. It had consisted of two fully developed members, of which the radial member had been slightly shorter than the ulnar and had been amputated when the draftee was 6 years of age. A postoperative scar was present at the site of amputation, over the radial aspect of the left first metacarpus, just distal to its head.

The right thumb was not bifid. The nail phalanx of the right thumb was deviated radialward, while the nail phalanx of the left thumb presented slight ulnarward deviation (fig. 1).

The metacarpal phalangeal joint could be palmarly flexed between 180 and 100 degrees in the right thumb and between 180 and 120 degrees in the left thumb.

The greatest range of motion was possible in the proximal interphalangeal joint, which could be moved from 180 to 80 degrees in the right thumb and from 190 to 75 degrees in the left thumb. The nail phalanx had the least motion, being restricted to between 180 and 175 degrees in the right thumb and between 180 and 170 degrees in the left thumb.

A roentgenogram (fig. 1 *B*) showed that both thumbs had three phalanges. The proximal and the nail phalanx of each thumb presented nothing unusual in shape and size. The middle phalanx of the left thumb was fairly well formed and resembled somewhat the middle phalanx of the fifth finger, except that it was somewhat stouter and shorter than the latter. It is impor-

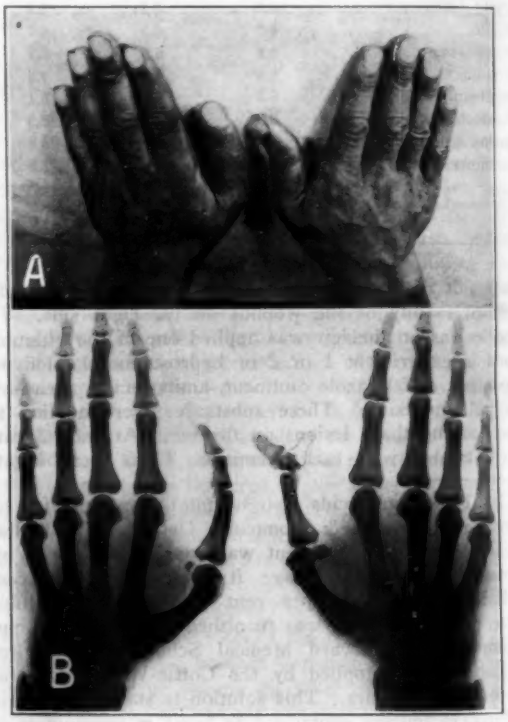

Fig. 1 (case 1).—*A*, photograph of both hands. Note the radial deviation of the nail phalanx of the right thumb and the ulnar deviation of the left thumb. A postoperative scar is visible at the base of the left thumb, resulting from amputation of the additional thumb. *B*, roentgenograms of both hands. Note the fully developed triphalangeal thumb on the left hand, with a triangular middle phalanx of the right thumb. The punctate line over the right thumb shows the apparently missing part of the bifid nail phalanx.

1. Lapidus, P. W.; Guidotti, F. P., and Coletti, C. J.: Triphalangeal Thumb: Report of Six Cases, Surg., Gynec. & Obst. **77**:178-186 (Aug.) 1943.

tant to mention also that the middle phalanx of the left thumb appeared somewhat trapezoid, a feature observed in many of the cases previously reported by us.[1]

The middle phalanx of the right thumb was small and wedge shaped, markedly resembling that in case 1 in our previous series.[1] The left first metacarpus was slightly shorter and somewhat stouter than the right. It had a larger head than the right, providing additional articular surface for the basal phalanx of the amputated radial member of the originally bifid thumb.

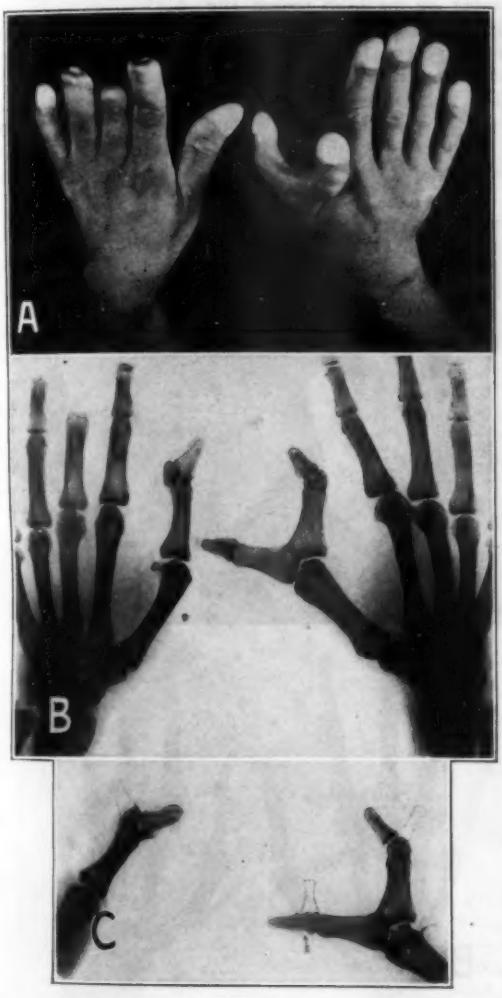

Fig. 2 (case 3).—*A*, photograph of both hands. Note the fully developed bifid right thumb and the unusually long left thumb. *B*, roentgenograms of both hands, showing the bifid triphalangeal right thumb and the triphalangeal left thumb. The head of the second metacarpal extends farther distally than those of the others, especially on the right side. *C*, dorsipalmar view of both thumbs. Note the "duck bill" appearance of the nail phalanx of the left thumb, with a perforation at the distal end. The punctate outlines represent the missing parts of the bifid nail phalanges. Note that the middle phalanx of the radial member of the right thumb is partially fused to the nail phalanx, so that no distal joint is present (arrow).

Except for this anomaly of the thumbs, the skeleton of the hands presented no peculiarities. The feet also appeared to be free from abnormalities, although no roentgenogram was available.

Case 2.—A Negro man aged 37 years was an accountant. His left thumb was triphalangeal; his right thumb was bifid distal to the metacarpal phalangeal joint and consisted of two similar radial and ulnar members, both triphalangeal and differing in that one was the mirror image of the other (fig. 2*A*).

On questioning, the draftee stated that his maternal uncle now deceased had had one bifid thumb. Another maternal uncle "had a straight right thumb without joints, which he was unable to bend." The draftee's mother was said to have both thumbs with the nail phalanx in radial deviation "exactly the same" as the draftee's left thumb. One of the draftee's brothers was reported to have an additional fifth finger, consisting of a small nail phalanx over the lateral aspect at the base of one of his fifth fingers; several cousins also were alleged to have this anomaly.

Examination of the hands revealed that the nail phalanges of the index, third and fourth finger of the left hand were amputated after an injury (fig. 2*A*). There was good motion of both thumbs, the right thumb (bifid) moving in toto.

The roentgenograms of the hands (fig. 2*B* and *C*) showed that the right first metacarpal bone was somewhat stouter than the left. Its head was V-shaped, articulating with the base of the two proximal phalanges of the bifid thumb. The adjacent surfaces of the bases of the proximal phalanges were fused together, forming a V-shaped common articular facet for the metacarpal head.

The ulnar member of the right thumb had a small wedge-shaped middle phalanx, which formed two distinct joints with the proximal and the nail phalanx respectively. The nail phalanx of the ulnar member of the right thumb was deviated radialward, pointing toward the radial thumb. The middle phalanx of the radial member of the right thumb was about the same size as the one on the ulnar side. It formed, however, only one distinct articulation with the head of the proximal phalanx (fig. 2*B* and 2*C*). The distal interphalangeal joint of the radial member of the right thumb apparently had failed to develop; it was represented by an hourglass constriction with a faint transverse line in the otherwise bony fusion of the middle and nail phalanges.

The left thumb was triphalangeal, with a practically normal-shaped nail and proximal phalanx. The small triangular middle phalanx (similar to that in case 1 in our previous series[1]) was interposed between the ulnar halves of the base of the nail phalanx and the head of the proximal phalanx. On the radial side, the head of the proximal phalanx and the base of the nail phalanx articulated directly with each other. The nail phalanx of the left thumb deviated radialward and had a small round hole at its distal end suggestive of the "duck bill" appearance described by Haas[2] (fig. 2*C*). Likewise, the nail phalanx of the ulnar member of the right thumb had a small round hole in its distal end, better seen in figure 2*B*.

Two sesamoids were present on the palmar aspect of the first metacarpal head of both hands. The second metacarpal head of both hands extended more distally than the third, the third finger, however, being longer than the second. No abnormalities were found over the carpal bones or at the joints of the wrists.

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2. Haas, S. L.: Three-Phalangeal Thumbs, Am. J. Roentgenol. **42**:677-682 (Nov.) 1939.

The feet were clinically normal. Roentgenograms of the feet presented no abnormalities except that there was a bifid right first tibial sesamoid, which possibly was an ununited fracture.

CASE 3.—A white truckman aged 18 presented a bifid right thumb with two separate nails (fig. 3 *A*). The two right thumbs were fused except for a small distance over the distal half of the nail phalanx.

There was no known deformity in two generations.

The roentgenogram (fig. 3 *B*) showed no abnormalities at the wrist or fingers except for the right thumb. The right first metacarpus was normal. The basal phalanx of the right thumb was somewhat thicker than the left and terminated in two round heads. The radial head articulated with a small middle phalanx, which in its turn articulated with the thin nail phalanx. The ulnar head of the basal phalanx articulated with a small wedge-shaped ossicle, which was interposed between it and the base of the nail phalanx. The nail phalanx was normally shaped, and the ulnar part of its base articulated directly with the ulnar head of the basal phalanx. This also was an instance of a combination of bifid and triphalangeal thumb. Furthermore, the radial member of the bifid thumb had a fully formed middle phalanx, while the ulnar member had only a small wedge-shaped ossicle interposed only on the radial side between the basal phalanx and the nail phalanx. Thus the radial thumb resembled somewhat the thumbs in cases 2, 3 and 4 of our previous series[1]; the ulnar thumb was similar to that in case 1 of that series.

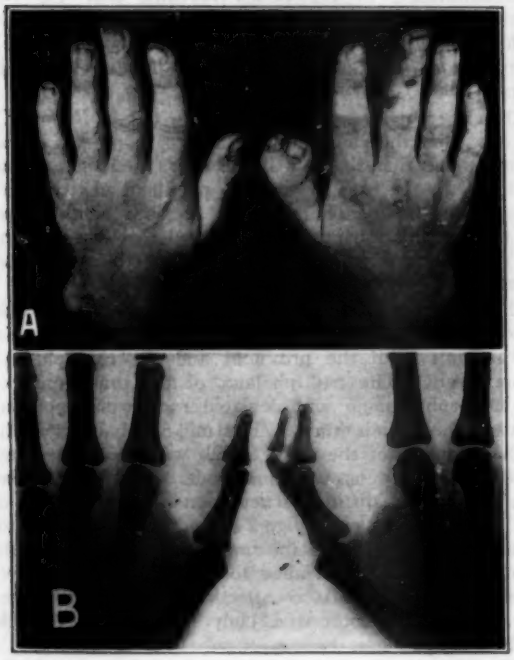

Fig. 3 (case 3).—*A*, photograph of both hands, showing the bifid right thumb. Note also the radial deviation of the nail phalanges of both fifth fingers (clinodactylism). *B*, roentgenogram of the thumbs. Note the bifid right thumb; the radial member is definitely triphalangeal, while the ulnar member has a small third phalanx interposed between the nail and the proximal phalanx only on the radial side.

No roentgenogram of the feet was taken, but they appeared to be normal.

CASE 4.—A white clerk aged 18 years was not aware of any malformations in three generations of his family. His feet and left hand were normal.

The right thumb was bifid, with a normally shaped ulnar member and a small separate radial member. There was good mobility of the bifid right thumb. The draftee apparently used mainly the large ulnar member of the bifid thumb (fig. 4 *A*).

Roentgenograms (fig. 4 *B*) of both hands showed what appeared to be bony fusion between the greater and lesser multangular bones of both wrists.

The right thumb was bifid. The right first metacarpus was slightly shorter and thinner than the left. It continued distally into the normally shaped two phalanges of the ulnar thumb. An additional small triphalangeal thumb was attached by only soft tissue to the radial aspect of the base of the first metacarpal. This radial member consisted of a small round ossicle (apparently a basal phalanx), which did not form any definite articulation with the first metacarpus but articulated distally with a slender middle phalanx, which in turn articulated with a slender oblong nail phalanx.

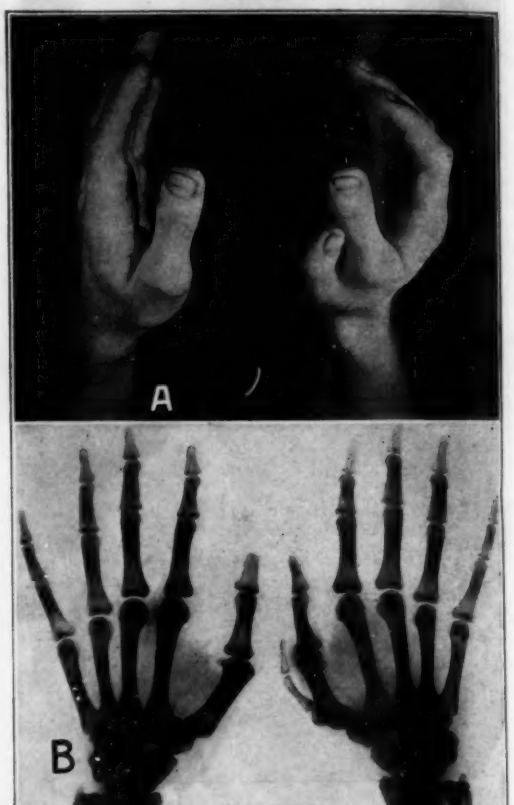

Fig. 4 (case 4).—*A*, photograph of both hands. *B*, roentgenogram of the hands. Note the bifid right thumb, the rudimentary radial member of which is triphalangeal.

CASE 5.—A white youth, aged 17 years, a baker's helper, had no history of any known abnormalities in three generations of his family.

The draftee's fingers were long and slender. Both thumbs were bifid and extremely long, being approxi-

mately the same length as the fifth finger. The two members of the right thumb were completely separate distal to the metacarpal phalangeal joint. The left thumb had a cutaneous webbing connecting its two members and extending distally to the level of the proximal interphalangeal joint (figs. 5 *A* and 5 *B*).

The thumbs of both hands had normal range of motion, although the radial and the ulnar member of the bifid thumbs could be moved only together simultaneously, separate motion of either member being impossible.

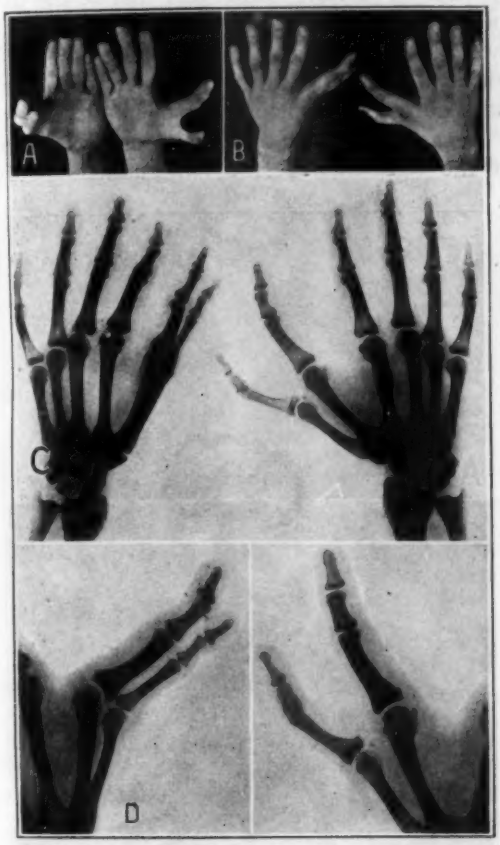

Fig. 5 (case 5).—*A* and *B*, photographs of both hands, showing the bilateral long bifid triphalangeal thumbs. Note the complete separation of the members of the right thumb, while the two members of the left thumb are connected with a soft tissue web, extending to the base of the nail phalanges. *C*, roentgenograms of both hands. Note the complete bifidism of the first rays, including the metacarpal bones. Both thumbs are triphalangeal. The left second metacarpal head extends farthest distally. The right second metacarpus originally apparently presented the same relation to the other metacarpal bones but became shortened by a fracture of its shaft. Note an additional ossicle (more visible on the right side) between the greater and lesser multangular bones articulating with the base of the first metacarpal of the ulnar thumb. *D*, dorsipalmar view of the thumbs, showing them in greater detail.

Roentgenograms of the thumbs (figs. 5 *C* and 5 *D*) showed that both thumbs consisted of two fully developed rays. Each double thumb consisted of two fully developed, separate first metacarpal bones, with three phalanges for each member of the bifid thumb. The ulnar member of the thumb on each hand was somewhat larger and better developed, especially on the right side, than the radial member.

Fig. 6 (case 6).—Roentgenogram of the left hand, showing a trifid thumb, the radial member of which divides distally into two separate members, while the ulnar member has a normal appearance. Note that the middle thumb is triphalangeal with an underdeveloped distal interphalangeal joint. Note also the rather short, stout first metacarpal. The second metacarpal head extends farthest distally.

An additional small ossicle was present between the greater and the lesser multangular bone of each hand. This ossicle articulated with the base of the first metacarpal of the ulnar thumb.

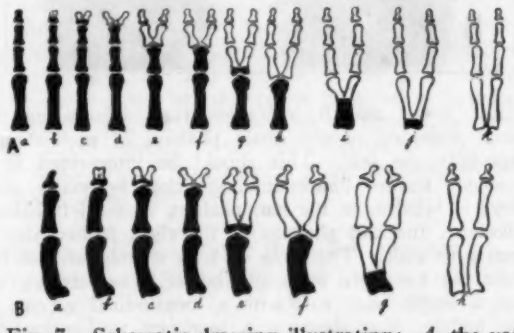

Fig. 7.—Schematic drawing illustrating: *A*, the various stages of longitudinal splitting, or bifidism, of the digital rays; *B*, the same stages as they occur in the first digit.

There was no other abnormality at the joints of the wrists. The right second metacarpal was somewhat deformed as the result of an old fracture.

CASE 6.—This subject [3] was also seen at the induction station, but no detailed history is available.

3. Courtesy of Dr. A. Sager.

The draftee presented a left trifid thumb. As the roentgenogram shows (fig. 6), the first metacarpal was somewhat shorter and stouter than usual. Its broad head articulated with two entirely separate proximal phalanges. The ulnar member of the trifid thumb had a normally developed nail phalanx. The radial thumb was split distally again into two separate thumbs. The head of its proximal phalanx articulated with the nail phalanx on its radial side. On its ulnar side it articulated with a square middle phalanx, to which a nail phalanx was fused by bone. Thus the middle member of the trifid thumb apparently was also triphalangeal, but its distal interphalangeal joint failed to develop fully.

COMMENT

The 6 cases here reported illustrate the occurrence of a combination of triphalangeal thumb with bifid thumb in the same person with a trifid thumb in the sixth case. In 2 of the 6 cases there was a history of the presence of a similar deformity in the family.

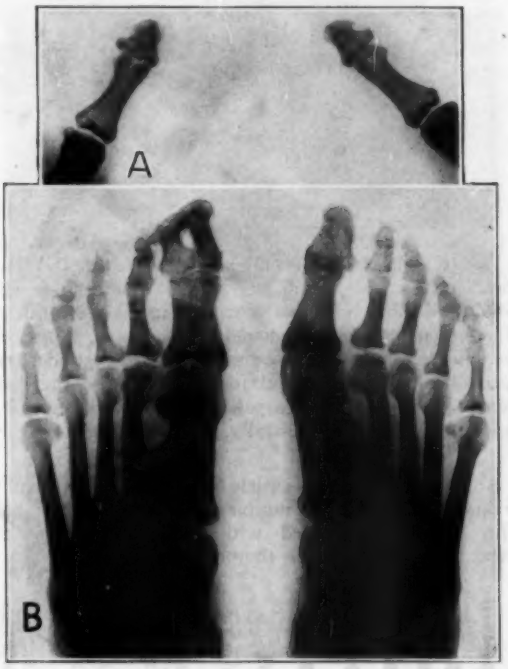

Fig. 8.—*A* and *B*, roentgenograms illustrating unusual widening of the distal phalanx of each thumb, especially the left. This should be interpreted as a tendency toward longitudinal splitting, especially since there is bifidism of the nail phalanx of the left hallux. Likewise, the nail phalanx of the right hallux also is unusually wide. The nails of both thumbs and of the right big toe were unusually large. The left big toe had a single wide nail with a longitudinal groove in the middle, also showing a tendency to longitudinal division.

In case 1, the remaining ulnar member of the bifid left thumb was triphalangeal. We have no way of knowing whether the amputated radial member also consisted of three phalanges, but the fact that a bifid thumb was present is evident.

In case 2, there was a definite combination of bifidism with triphalangism of both the radial and the ulnar member of the bifid thumb. On the left side the thumb was not bifid but was triphalangeal, having a triangular middle phalanx. It is significant also that the nail phalanx of the left thumb and that of the ulnar member of the right thumb in this case presented the "duckbill" appearance (figs. 7 *A b* and 7 *B b*), which we interpreted as the most rudimentary stage of longitudinal splitting, or bifidism.

In case 3, bifidism and triphalangism occurred in the right thumb, the longitudinal splitting, however, extending only through the middle and the nail phalanges of the thumbs. The basal phalanx of the right thumb presented only doubling of its head.

Fig 9.—*A* and *B*, illustrations of the second stage (figs. 7 *Ab* and 7 *Bb*) ("duck bill" appearance). Note widening of the distal portion of the nail phalanx of the left hallux, with a small hole in its center (arrow). While the skeleton of the left big toe does not show any definite longitudinal splitting, the soft tissues, as shown in *B*, have undergone complete longitudinal splitting, so that the left big toe has two separate toe nails.

Case 4 illustrates bifidism of the right thumb with a fully developed biphalangeal ulnar member. The rudimentary radial member was triphalangeal and was attached to the ulnar thumb only by soft tissue.

Case 5 is most interesting because of the combination of three well developed phalanges of the thumbs with complete splitting of the first ray and doubling of the first metacarpal on both sides.

Case 6 illustrates the most unusual combination of trifid thumb with apparent triphalangism. A longitudinal splitting of the proximal phalanx of the thumb resulted in a bifid thumb. The radial member of the bifid thumb had in its turn also undergone a longitudinal splitting, extending only through its distal phalanx; thus there were one metacarpus, two proximal phalanges and three nail phalanges. The middle member of the trifid thumb presented evidence of triphalangism with an undeveloped distal interphalangeal joint; the radial and ulnar members on both sides of the triphalangeal thumb were biphalangeal.

Fig. 10.—Roentgenograms illustrating gradually progressive longitudinal splitting of the thumb, corresponding to the stages illustrated in figures 7 *Bc*, *d* and *f* respectively.

A study of a large number of examples of polydactylism encountered among the draftees indicates that this anomaly and its various manifestations practically always conform to the following rule, as also observed by Mueller[4] and others: The supernumerary digits are the result of a more or less complete longitudinal splitting of the rays of the originally pentadactyl limb.

Figure 7 *A* schematically illustrates the various stages of this longitudinal splitting, or "bifidism," of the rays. It can be seen that this division starts distally in cases of mild deformity and extends proximally in cases of more pronounced deformity.

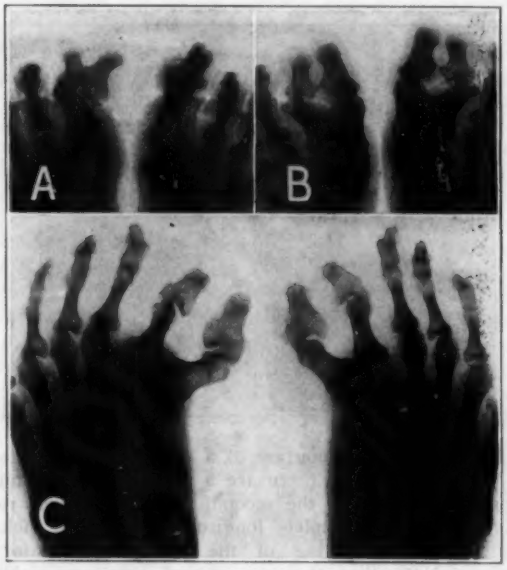

Fig. 11.—Roentgenograms illustrating different progressive stages of similar longitudinal splitting of the big toe. Note that in *A* the nail phalanx of the right big toe presents a "duck bill" appearance, corresponding to figures 7 *Ab* and 7 *Bb*, while the nail phalanx of the left big toe has undergone longitudinal splitting to a greater degree, corresponding to figures 7 *Ac* and 7 *Bc*. B corresponds to the stage illustrated in figures 7 *Ae* and 7 *Be*. *C* corresponds to the stage illustrated in figures 7 *Ah* and 7 *Bf*.

Figure 7 *B* illustrates the same process as it occurs in the first digit, which has only two phalanges.

As seen in figure 7 *A*, the bifidism may range from slight enlargement of the nail phalanx with a hole in its distal end (fig. 7 *A b* and *B b*) ("duck bill" appearance of Haas) to a complete duplication of the entire ray, including the metacarpal or the the metartarsal bones (fig. 7 *A k* and *B h*).

4. Mueller, W.: Die angeborenen Fehlbildungen der menschlichen Hand Erb-und Konstitutionsbiologie der Hand, Leipzig, Georg Thieme, 1937.

Various degrees of bifidism of the digital rays of the extremities have been encountered among the draftees. It is not within the scope of this paper to present all of the cases which would illustrate each of the stages of bifidism represented in figs. 7 *A* and 7 *B*. However, a few of the more striking examples are shown (figs. 8 through 12).

From the cases presented it is apparent that bifidism is not an infrequent occurrence and develops according to a definite pattern. The digital ray undergoes longitudinal splitting, which begins at the periphery and progresses proximally in cases of more advanced deformity. From the 6 cases presented here and the previously reported 6 cases it is obvious that there is a close relationship between bifidism and triphalangism of the thumb.

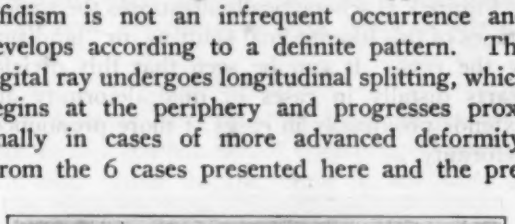

Fig. 12.—Roentgenogram of a normal right foot and a left foot in which there are a single first ray and a single fifth ray, but the second, third and fourth rays have undergone complete longitudinal splitting, including complete doubling of the respective metatarsal bones. Note that the two second toes are webbed together, while the other toes are completely separated.

Figure 13 illustrates graphically our theory concerning the development of triphalangism of the thumb. It may be assumed, as shown in this figure, that the phalanges of the originally bifid thumb (shown striated in the figures) failed to develop fully, while the bases of these phalanges (shown in solid black) still persist and simulate the third phalanx.

The evolution of triphalangism of the thumb probably follows most frequently the pattern illustrated in fig. 13 *A*, since in most of our cases the deformity resembled morphologically the patterns illustrated in figures 13 *A a, b, c, d* and *e*. In only 1 case (case 6, figure 12 in our previous article[1]) the pattern apparently followed the one illustrated in figure 13 *B b*. We have never observed the condition illustrated in figure 13 *B c* but may postulate its existence.

SUMMARY AND CONCLUSIONS

Five cases of triphalangism associated with bifidism of the thumb and 1 case of triphalangism combined with trifidism were studied. A history of heredity of the anomaly was established in 2 of them.

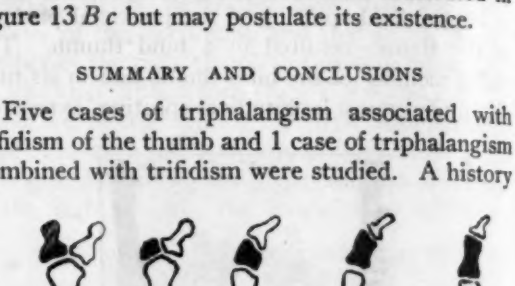

Fig. 13.—Drawing illustrating the development of triphalangism of the thumb.

Polydactylism must be regarded as a tendency toward longitudinal splitting of the originally pentadactyl limb. This splitting begins distally and extends proximally in cases of more advanced deformity.

The cases reported seem to substantiate the postulations set forth by us in a previous publication,[1] to the effect that the additional phalanx of a triphalangeal thumb is not a true phalanx similar to those in the lesser fingers but rather is a remnant of the base of one of the phalanges of a bifid thumb.

VENOUS PRESSURE AS AN INDEX OF BLOOD FLOW IN THE UPPER EXTREMITY

GEORGE W. DUNCAN, M.D.
BALTIMORE

In 1909 Hewlett and Van Zwaluwenberg [1] described a method of determination of the rate of blood flow in the arm. The method consisted essentially in placing the upper extremity in a plethysmograph and measuring the initial increase in volume of the limb when the venous outflow was occluded by a pressure lower than the diastolic pressure. This principle has more recently been applied to more refined methods of determining the rate of blood flow in both upper and lower extremities.[2] Since vascular engorgement of an extremity is obvious when venous occlusion is produced, the idea suggested itself that measurement of the rate of rise in venous pressure in one of the large veins of the forearm might be to some degree indicative of the rate of blood flow in the extremity. If such a simple method can be developed from this preliminary study and by subsequent comparison with plethysmographic methods, the clinical estimation of peripheral blood flow in a variety of medical and surgical conditions may be greatly facilitated.

METHODS AND RESULTS

Patients of various ages from surgical wards, either before operation or several days after operation, were used as subjects. They were covered with a single blanket and observed in a reclining position, usually one to three hours after the last meal. The experiments were carried out in a laboratory in which no provision was made for maintaining constant temperature; however, the variation in room temperature was not great. The arterial and venous pressures were determined at the beginning of the experiments. The apparatus used consisted of an ordinary venous pressure apparatus to which a small mercury U tube manometer had been attached. The venous pressure apparatus was connected to the mercury manometer by means of a column of isotonic solution of sodium chloride. An 18 gage needle was inserted into one of the large veins of the forearm at the elbow; in most cases the median antecubital vein was used, although occasionally one of the other branches of the basilic or the cephalic vein was used. The needle was connected to the venous pressure apparatus and a three way stopcock interposed at the site of the needle, for the purpose of washing out the needle and the adjacent tubing between readings. The venous pressure apparatus was placed at approximately the level of the heart, and as soon as the normal pressure was determined the zero reading of the manometer was raised to the level of the venous pressure. One or 2 cc. of 2.5 per cent solution of sodium citrate was used to prevent clotting in the needle between readings.

Venous occlusion was obtained by an ordinary blood pressure cuff, applied about the upper part of the arm. The pressure to which the cuff was raised was in all cases approximately 10 mm. of mercury below the previously measured diastolic pressure. The remainder of the experimental procedure was carried out by two different methods. Although the differences between the two were slight and the results obtained were similar, for clarity of description the experiments may be referred to as groups 1 and 2. In the first group the blood pressure cuff was rapidly inflated to the desired level by means of a hand bulb, while in the second group the cuff was more rapidly inflated from a 15 gallon (58 liter) bottle reservoir. Observations were made at room temperature and during local application of controlled heat and cold to the extremity. Control of the temperature of the extremity was obtained in the first group by placing the hand and wrist, which were covered with an ordinary rubber glove, in a glass water bath in which the temperature was maintained constantly within plus or minus 1 degree of the desired level. In the second group of experiments a longer rubber glove was used than in the first group; thus the hand, the wrist and in addition the lower two thirds of the forearm were in the water bath. In all instances the extremity was allowed to remain in the water bath at least ten minutes before a reading was taken.

In both groups of experiments when the needle was inserted into the vein and the cuff inflated the venous pressure began to rise immediately. The rate of rise of the venous pressure was measured by means of a stopwatch graduated to the tenth of a second. Since the rate of rise was more uniform after the pressure had reached 20 to 25 mm. of mercury, in the first group of experiments the index chosen was the time required for the pressure to rise from 25 to 35 mm. of mercury. In the second group the index used was the time required for the pressure to rise from 0 to 40 mm. of mercury. Readings were made at frequent intervals. In the first group the extremity was observed at room

From the Department of Surgery, Johns Hopkins University School of Medicine, and Johns Hopkins Hospital.

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temperature, and after several such readings the patient was instructed to exercise the hand and forearm by rapid repeated grippings for periods of two minutes. At the end of each two minute period the rate of rise in venous pressure was observed and recorded. After several such readings the extremity was placed in a water bath at 10 or 15 C. and the rate of rise in venous pressure observed. This was followed by the same procedure with the water bath at 42 C. In the second group of experiments similar observations were made but in a different sequence. The effects of heat and cold were observed, followed by observations at room temperature and following exercise.

TABLE 1.—*Results of the Experiments in Group 1**

		Room Temperature		Exercise and Room Temperature		Local Application of Cold			Local Application of Heat		
Patient and Condition	Reading	Seconds Required for Venous Pressure Rise	Temperature, C.	Seconds Required for Venous Pressure Rise	Temperature, C.	Seconds Required for Venous Pressure Rise	Bath Temperature, C.	Room Temperature, C.	Seconds Required for Venous Pressure Rise	Bath Temperature, C.	Room Temperature, C.
G. B., aged 54; carcinoma of buccal mucous membrane; before operation	1	27.8	29.4	4.9	29.5	28.0	15.0	29.5	7.8	42.0	29.4
	2	17.8	29.5	5.4	29.5	37.0	15.6	29.3	7.3	42.2	29.5
	3	18.0	29.3	5.4	29.5	30.0	15.0	29.0	6.8	42.1	29.5
	4	16.2	29.5	6.6	29.4	37.7	15.1	29.4	6.8	41.8	29.6
	5	15.2	29.4	6.7	29.4	25.4	15.3	29.0	7.1	42.0	29.0
M. M., aged 46; nontoxic adenoma of thyroid; twelfth postoperative day	1	12.8	29.8	5.0	30.0	18.2	15.0	30.1			
	2	19.7	29.9	5.0	30.0	23.0	15.0	29.9			
	3	13.5	29.9	4.2	30.0	26.4	15.6	30.0			
	4	11.0	29.9	4.2	30.1	19.6	15.4	30.2			
	5	7.2	30.0	3.4	30.1	29.9	15.0	29.9			
	6	9.0	30.0								
	7	10.7	30.1								
R. P., aged 56; hemorrhoids; seventh postoperative day	1	62.0	26.6	1.9	27.6	31.1	10.5	27.6	7.3	42.0	27.3
	2	31.4	26.5	2.2	27.6	25.5	10.6	27.3	8.2	42.0	27.0
	3	24.0	26.8	4.2	27.7	20.0	11.0	27.0	8.9	42.9	27.4
	4	22.9	27.1	4.3	27.7	31.7	10.0	27.0	9.2	42.0	27.0
	5	22.6	27.2	3.3	27.7	27.0	10.1	26.5			
	6	13.5	27.3			37.9	10.5	27.0	8.2	41.5	26.8
	7	11.5	27.5								
	8	10.6	27.5								
	9	13.7	27.4								
	10	11.3	27.3								
V. V., aged 22; tumor of pharynx; before operation	1	9.5	27.5	6.1	27.6	22.2	15.0	27.6	9.0	42.0	27.3
	2	7.8	27.6	4.0	27.7	25.3	16.0	27.0	5.7	42.3	27.3
	3	10.4	27.5	4.2	27.8	38.4	15.1	27.3	6.0	42.1	27.2
	4	13.2	27.6	3.9	27.5	23.5	15.3	27.0	6.5	42.0	27.0
	5	11.5	27.6	2.6	27.8	33.0	14.9	27.4	6.2	41.9	27.8

* The time in seconds required for venous pressure in the large veins of the forearm to rise from 25 to 35 mm. of mercury was determined. Observations were made at room temperature, followed by local application of cold and heat to the hand and wrist.

TABLE 2.—*Results of the Experiments in Group 2**

		Local Application of Heat			Local Application of Cold			Room Temperature		Exercise and Room Temperature	
Patient and Condition	Reading	Seconds Required for Venous Pressure Rise	Bath Temperature, C.	Room Temperature, C.	Seconds Required for Venous Pressure Rise	Bath Temperature, C.	Room Temperature, C.	Seconds Required for Venous Pressure Rise	Temperature, C.	Seconds Required for Venous Pressure Rise	Temperature, C.
R. H., aged 16; acute appendicitis; seventh postoperative day	1	22.3	39.8	25.3	41.0	20.1	25.3	28.5	25.5	5.2	25.0
	2	18.2	40.0	25.3	41.4	20.1	25.2	29.5	25.3	7.2	25.1
	3	18.8	39.6	25.1	47.0	20.0	25.4	24.0	25.3	5.0	25.0
	4	17.6	39.8	25.1	45.0	20.5	25.2	23.8	25.0	3.0	25.0
	5	16.5	40.0	25.1	55.4	20.2	25.0	24.9			
	6	18.4	40.0	25.0	60.0	20.3	25.5				
C. C., aged 47; stenosis of common bile duct; before operation	1	17.1	39.9	25.7	13.6	20.3	25.5	9.8	25.3	2.8	25.3
	2	9.0	39.0	25.5	15.3	20.3	25.3	11.1	25.3	3.4	25.3
	3	7.5	40.1	25.5	23.6	20.3	25.0	8.9	25.3	4.4	25.3
	4	7.0	39.7	25.5	31.5	20.4	25.0	11.5	25.3	3.4	25.4
	5	5.5	40.1	25.5	32.4	20.3	25.0	8.5	25.5		
	6	8.3	40.1	25.5	27.6	20.5	25.0				
J. D., aged 22; nasal deformity; before operation	1	16.8	39.5	25.7	16.2	19.7	25.7	19.9	27.1	4.6	25.3
	2	12.3	39.5	25.7	20.9	20.3	25.5	14.7	24.6	4.7	25.4
	3	12.8	39.3	25.7	24.1	19.8	25.5	12.6	25.7	4.5	25.7
	4	10.9	39.1	25.5	25.7	20.2	25.5	17.1	25.0	4.0	25.6
	5	13.8	39.8	25.5	28.2	20.8	25.5				
	6	12.1	40.1	25.7	25.9	20.2	25.5				
	7	10.4	39.5	25.3	37.1	20.6	25.0				
					38.1	20.9	26.0				

* The time in seconds required for the venous pressure to rise from 0 to 40 mm. of mercury in the large veins of the forearm was determined. Observations were made on the effects of local application of heat and cold to the hand, the wrist and the lower two thirds of the forearm, followed by determinations at room temperature and following two minute periods of exercise.

The results obtained were similar in both groups of experiments. Exact duplications of figures for various patients were not obtained, but similar trends were observed for all of them.

In all patients the initial rate of rise in venous pressure was slower than the rate in succeeding determinations. This increase in rapidity of rise quickly reached a fairly uniform rate and remained there. It has been observed by Freeman [2a] and others that the blood flow in an extremity is greatly influenced by changes in temperature of the extremity; the application of heat increases the blood flow, while the application of cold decreases it. In the experiments described here the application of heat in all cases increased the rate of rise of the venous pressure, an observation which coincides with that of Freeman and others. Likewise, the application of cold to the extremity invariably produced a decrease in the rate of rise in venous pressure. Exercise of the muscles of the forearm and hand for two minutes produced a pronounced increase in the rate of rise in venous pressure, the increase being greater than that produced by the local application of heat (40 to 42 C.).

COMMENT

These observations indicate that the rate of rise in venous pressure in the large veins of the forearm reflects to some degree the rate of blood flow in an extremity. When the venous outflow from an extremity is suddenly occluded by a pressure lower than the diastolic pressure, the arterial inflow continues. The incoming blood progressively distends the arterial, capillary and venous systems, increasing the volume in the arm. The initial rapid arterial inflow represents the normal rate of inflow. Gradually this rate decreases as the pressure rises in the capillary and venous systems. The rise in pressure in the venous system, as measured in these experiments, is probably a later phase in the process than the initial increase of volume, which is used as an index in the plethysmographic methods. The brief period required for the filling of the vascular system is apparent when one observes the mercury manometer; the initial rise is slower than the more rapid steady rise which quickly follows. Subsequent studies will be made in order to compare the pressure curves obtained by this method with the curves obtained by the plethysmographic methods and to determine the possible variations produced by elasticity of the vessel walls, vasomotor tone, skeletal muscle tone and tissue pressure.

The exact relationship between the results obtained by the plethysmographic methods and the results obtained in these experiments is difficult to state, since different units of measurement are used. However, these experiments give some indication of the blood flow, since factors which previously have been shown to alter the rate of blood flow in an extremity produced identical responses in these experiments.

SUMMARY

In the experiments described here the measurement of the rate of rise in venous pressure in the large veins of the forearm following venous occlusion is, at least to some extent, an index of the rate of blood flow in the extremity. Local application of heat to the hand and forearm and exercise of the muscles of the hand and forearm increase the rapidity of rise in venous pressure, while local application of cold decreases it.

INTRAVENOUS ADMINISTRATION OF DEXTROSE IN THE TREATMENT OF PATIENTS WITH DISEASE OF THE BILIARY TRACT

H. A. ZINTEL, M.D.; CECILIA RIEGEL, PH.D.; ROZANNE PETERS, A.B., AND J. E. RHOADS, M.D.

PHILADELPHIA

AND

COLONEL I. S. RAVDIN

MEDICAL CORPS, ARMY OF THE UNITED STATES

Determination of the glycogen and lipid content of samples of liver obtained from patients in the course of operations on the biliary tract indicated that the diet high in carbohydrate and protein advocated by us [1] was more effective in decreasing the fat content of the liver than in elevating the glycogen content. The present study was undertaken to determine the effectiveness of intravenous administration of dextrose during the twelve hours preceding operation in increasing liver glycogen in patients with disease of the biliary tract.

The value of giving intravenous infusions of dextrose solution to patients with disease of the biliary tract in preparation for surgical treatment has at times been overemphasized. Nevertheless, when used as a supplement to a suitable diet and not as a substitute for diet they appear to be useful. Many of these patients show histologic evidence of hepatic damage at operation, and it seems of particular interest to determine whether a high level of liver glycogen would be found in such patients after infusion of dextrose.

PROCEDURE

Eighteen patients with varying degrees of disease of the biliary tract requiring surgical operation were studied. Two liters of 10 per cent dextrose solution was administered to each patient by continuous venoclysis for about twelve hours preceding operation. The operative procedure was carried out with the patient under spinal anesthesia in every instance. At the close of each operation approximately 0.5 Gm. of tissue was removed from the anterior margin of the liver, and a portion of this specimen was immediately placed in potassium hydroxide solution for determination of glycogen. Chemical and histologic analyses were made of all specimens removed. After removal of the portion of the specimen for determination of glycogen, the remainder of the specimen was divided into two equal parts, one for histologic study and the other for determination of fat content. Determinations of liver glycogen were made by the method of Good, Kramer and Somogyi.[2] Mam and Long's [3] modification of the Stoddard and Drury [4] method was used for determinations of fat.

RESULTS

Biopsy specimens of the liver from 58 patients with disease of the biliary tract were studied. Eighteen of the patients received dextrose intravenously prior to operation. The average glycogen content of the liver of those patients was 6.1 per cent. The highest value observed in this group was 10 per cent, and the lowest was 2.5 per cent. In analyses of biopsy specimens of the liver of a group of 40 other patients with disease of the biliary tract who were not treated with dextrose administered intravenously, the average glycogen content was 2.8 per cent. Thus the average glycogen content of the liver in the group of patients treated with intravenous administration of dextrose was 118 per cent higher than that in the group of 40 patients who did not receive dextrose intravenously.

Those of the 18 patients who were given dextrose intravenously and who had histologic evidence of some hepatic damage had an average liver glycogen level of 5.7 per cent. This level of 5.7 per cent was 104 per cent higher than the

From Surgical Service B, Hospital of the University of Pennsylvania and The Harrison Department of Surgical Research, University of Pennsylvania School of Medicine.

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average glycogen level of the control group. Thus it is possible to produce a significant elevation of the glycogen content of the liver in the presence of moderate hepatic damage. None of the patients studied had histologic evidence of severe hepatic damage.

COMMENT

It has long been recognized that the damaged liver contains an increased amount of fat and little glycogen.[5] Rosenfeld[6] demonstrated that animals fed on carbohydrate are less susceptible to drugs which cause hepatic damage and increase in liver fat and furthermore that once hepatic damage is established recovery is aided by feeding of carbohydrate. Davis, Hall and Whipple,[7] Opie and Alford[8] and Graham[9] demonstrated experimentally the resistance of liver containing increased amounts of glycogen to hepatic damage produced by chloroform or phosphorus. A high carbohydrate intake was shown by Bollman and Mann,[10] Ravdin,[1a] and others to reduce the degree of hepatic damage following experimental ligation of the common bile duct.

Large quantities of dextrose were first used at the suggestions of Beddard[11] for the treatment of patients with hepatic damage following chloroform anesthesia. Jones[12] found that the more intensive the dextrose therapy the better the prognosis for patients with acute hepatic insufficiency. Regardless of whether or not carbohydrate acts directly or indirectly in protecting the liver against damage or in aiding recovery, if damage has already occurred carbohydrate has come to be regarded as of value clinically.

There have been differences of opinion among the proponents of carbohydrate therapy concerning the advantages of intravenous administration of dextrose if the patient is able to take large amounts of carbohydrate by mouth. MacIntyre and associates[13] have shown that supplementary dextrose given by mouth will raise the glycogen content of the normal liver, but they were not successful in raising the glycogen level of the severely damaged liver above 2.9 per cent, which is approximately the average normal glycogen content of the undamaged liver. More carbohydrate can be deposited in the liver if dextrose is given by the intravenous route than if an equivalent amount is given by mouth. The explanation for this probably lies in the fact that higher blood sugar levels are obtained when dextrose is administered by vein than when administered by mouth. Cori and Cori[14] have pointed out that the blood sugar level to a large extent determines the amount of glycogen deposited in the liver and that this deposition is not determined by the total amount of dextrose administered.

This fact can be further demonstrated in this experiment if our data are compared with those of MacIntyre and associates.[13] In each experiment the same amount of dextrose was used, namely 200 Gm. MacIntyre's patients received this amount by mouth during the twelve hours preceding operation, whereas the patients reported on here received the same amount intravenously during the twelve hours preceding operation in the form of 2,000 cc. of 10 per cent dextrose. The patients who received dextrose by mouth showed a 60 per cent increase in liver glycogen, while those who received dextrose intravenously showed an increase of 118 per cent. Thus when 200 Gm. of dextrose is administered by vein a higher glycogen content results than when the same amount is given by mouth.

Goldschmidt, Vars and Ravdin[1b] demonstrated that the degree of hepatic damage following chloroform anesthesia is proportional to the fat content of the liver. They concluded that a higher concentration of hepatic glycogen, per se, fails to confer any discernible protection against the hepatotoxic action of chloroform in rats with the same concentration of hepatic fatty acids and similar intakes of protein. Johnson and

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co-workers [15] showed that a diet high in protein and carbohydrate and low in fat was as effective in one week in reducing liver fat in the dog with obstructive jaundice as a high carbohydrate diet was in two weeks. Protection of the liver against damage, therefore, resolves itself into the positive action of protein, the indirect action of carbohydrate and the negative action of fat.

The results of administration of a diet high in carbohydrate and protein, low in fat and high in calories for five days or more before operation, while excellent from the standpoint of reducing the fat content of the liver, were not impressive from the standpoint of the degree of elevation of the glycogen level. The average increase of liver glycogen after such a diet in patients with severe hepatic damage was 10 per cent.[16] On the other hand, there was no evidence in the patients who received dextrose intravenously that the fat content was significantly lowered.

In the light of these findings, the optimum preparation of patients with hepatic damage for surgical operation would probably be obtained with administration of a diet high in protein and carbohydrate and low in fat over five to fourteen days, supplemented by intravenously administered dextrose for a period immediately prior to operation.

The need for dextrose preoperatively in patients with hepatic damage becomes more apparent when one realizes that as much as 45 per cent of the liver glycogen may be lost during the course of a long operation, as reported by Ariel, Pack and Rhoads.[16]

Liver glycogen is so labile that if one desires to maintain it at a high level during an operation intravenous administration of dextrose is fully justified, especially during the period of fasting immediately before operation. Its administration may, of course, be continued throughout the operation and into the postoperative period.

SUMMARY

Biopsy specimens of the liver were taken from a group of 58 patients with disease of the biliary tract. Eighteen of these patients received dextrose intravenously before operation, and the remaining 40 patients were controls and received no preoperative dextrose therapy intravenously.

The average glycogen level of the liver of the patients who received dextrose intravenously was 6.1 per cent, or 118 per cent greater than the average glycogen level of the control group.

The patients who had moderate hepatic damage, as judged by histologic studies, and who received dextrose intravenously had an average hepatic glycogen level of 5.7 per cent, or 104 per cent more than the level observed in the control patients.

Intravenous administration of dextrose without dietary supplement did not significantly lower the fat content of the liver in the patients observed.

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SUBARACHNOID ANALGESIA MAINTAINED BY THE CONTINUOUS DROP METHOD

JULIA G. ARROWOOD, M.D., AND FRANCIS F. FOLDES, M.D.
BOSTON

The method for inducing continuous spinal anesthesia introduced by Lemmon [1] in 1940 has transferred the procedure for obtaining subarachnoid block to the category of controllable methods. This has greatly increased its adaptability and safety. Recently we [2] described a continuous drop method for maintaining subarachnoid analgesia.

TECHNIC

In addition to the special mattress, malleable needle, tubing and stopcock of Lemmon, the equipment includes a 250 cc. leveling flask and tubing fitted with a Murphy dropper, a regulating valve and a glass adapter (fig.). After the lumbar puncture is accomplished and the patient turned to the recumbent position, the initial dose of anesthetic solution is given, as would be done with the fractional method of administration. For this dose we use 2.5 per cent procaine hydrochloride in a 2.5 per cent solution of dextrose in isotonic solution of sodium chloride. The size of the initial dose depends on the height of analgesia desired. For a cutaneous level to the third or fourth thoracic segment, which is adequate for an operation on the upper part of the abdomen, a good risk patient of average size will require 6 cc. of the solution, representing 150 mg. of procaine hydrochloride. As soon as the initial injection is made, the table is placed in a 5 degree Trendelenburg position and analgesia is established at the necessary level. The patient is then moved to the operating room, the operative field prepared and the incision made. Analgesia is maintained by the drop method. The leveling flask, containing 0.5 per cent procaine hydrochloride solution, is suspended 60 to 80 cm. above the level of the spinal needle. Twenty minutes after administration of the initial dose, the 2 cc. of the 2.5 per cent procaine hydrochloride solution remaining in the continuous spinal tubing (measured to contain exactly that amount) is withdrawn. The air is exhausted from the tubing of the leveling flask by permitting it to fill with 0.5 per cent procaine hydrochloride solution, and then the glass adapter is connected to the stopcock. Forty drops of the 0.5 per cent procaine solution is run in immediately to replace the 2 cc. of the 2.5 per cent procaine solution previously withdrawn. By calibration 20 drops of this solution represents 1 cc. Then the valve is regulated to deliver the desired number of drops per minute. The rate of dropping should be accurately timed by a stopwatch. For work on the upper part of the abdomen in the average patient it is necessary to adjust the flow to the rate of 8 drops per minute. If a lower level of analgesia is indicated or the patient is small, the rate should be slower. It is advisable to test the cutaneous level at intervals, in order to be assured that it has neither advanced nor receded. The rate of dropping may vary slightly with changes in the pressure of the spinal fluid. Usually it tends to become gradually slower. This should be checked every ten or fifteen minutes and the valve regulated to deliver the drops at the desired rate. Occasionally, although working conditions have been satisfactory throughout, additional relaxation is needed to close the peritoneum. This may be immediately obtained by letting 100 drops (representing 25 mg. of procaine in 5 cc.) go in rapidly. Then dropping is resumed at the usual rate and continued until the cutaneous stitches are started.

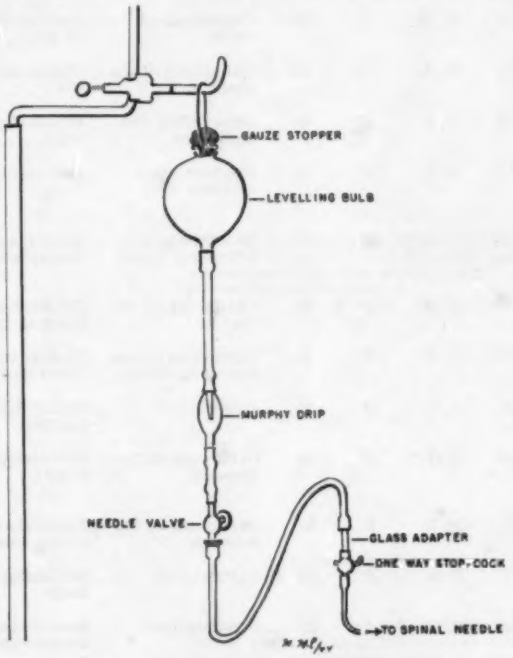

Diagram of apparatus.

The table contains a summary of the management of the first 27 consecutive cases in which the continuous drop method was used. In 11 cases the spinal anesthesia was supplemented with pentothal sodium to produce sleep and obtund the vomiting and traction reflexes. Usually the blood pressure was well maintained without the aid of adrenergic drugs, but it was necessary to give such a drug in 9 cases.

From the Department of Anesthesia of the Massachusetts General Hospital and the Anesthesia Laboratory of the Harvard Medical School at the Massachusetts General Hospital.

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No.	Name	Sex	Age, Yr.	Diagnosis	Operative Procedure	Premedication,* Mg.	Dose, Mg. Initial	Dose, Mg. Total	Spinal Level	Duration Hr.	Duration Min.
1	R. C.	♀	39	Intestinal polyposis	Removal of polyps	M.S. 10.0 A.S. 0.6 E.S. 50.0	100	190	Second dorsal	1	30
2	C. C.	♂	57	Carcinoma of perianal region	Radical dissection of left groin	Pento. 100.0 M.S. 10.0 A.S. 0.6 E.S. 50.0	100	255	Fifth dorsal	2	55
3	J. R.	♂	52	Carcinoma of bladder	Right ureteroenterostomy	M.S. 10.0 A.S. 0.6 E.S. 50.0	125	355	Third dorsal	2	..
4	A. P.	♂	64	Inguinal hernia	Gallie herniorrhaphy	M.S. 10.0 Scop. 0.3 E.S. 50.0	100	300	Sixth dorsal	2	45
5	A. G.	♂	58	Carcinoma of stomach	Subtotal gastrectomy	M.S. 10.0 A.S. 0.6 E.S. 50.0	150	720	Third dorsal	4	10
6	J. M.	♂	68	Duodenal ulcer	Second stage gastric resection	M.S. 10.0 A.S. 0.6 E.S. 50.0	150	260	Second dorsal	1	35
7	E. K.	♂	63	Duodenal ulcer	Subtotal gastrectomy	M.S. 10.0 A.S. 0.6 E.S. 50.0	150	535	Second dorsal	3	50
8	R. K.	♂	18	Duodenal ulcer	Second stage gastric resection	M.S. 10.0 A.S. 0.6 E.S. 50.0	150	350	Third dorsal	2	10
9	C. C.	♀	60	Metastatic carcinoma of vulva	Radical dissection of groin	M.S. 10.0 A.S. 0.6 E.S. 50.0	100	320	Fifth dorsal	3	30
10	G. P.	♂	24	Ventral hernia	Gallie repair	M.S. 10.0 A.S. 0.6 E.S. 50.0	125	425	Fourth dorsal	4	15
11	E. M.	♀	65	Carcinoma of vulva	Radical dissection of groin	M.S. 10.0 A.S. 0.6 E.S. 50.0	100	370	Fourth dorsal	3	40
12	C. S.	♀	69	Carcinoma of the cecum	Colectomy (right side)	M.S. 10.0 A.S. 0.6 E.S. 50.0	125	340	Third dorsal	3	..
13	T. P.	♂	46	Obstructing duodenal ulcer	Subtotal gastrectomy	M.S. 10.0 A.S. 0.6 E.S. 50.0	150	630	Fourth dorsal	4	15
14	S. N.	♂	52	Duodenal ulcer stomach	Subtotal gastrectomy	M.S. 10.0 A.S. 0.6 P.S. 150.0 E.S. 50.0	150	570	Third dorsal	3	55
15	N. N.	♀	68	Carcinoma of left side of colon	Resection of the descending colon	M.S. 8.0 A.S. 0.6 P.S. 150.0 E.S. 50.0	125	275	Third dorsal	2	5
16	G. M.	♂	63	Carcinoma of the bladder	Bilateral ureteroenterostomy	M.S. 15.0 A.S. 0.6 E.S. 50.0	150	370	Fourth dorsal	2	15
17	C. S.	♀	67	Carcinoma of the ascending colon	Ileotransverse colostomy	M.S. 10.0 A.S. 0.6 E.S. 50.0	125	265	Third dorsal	2	40
18	J. M.	♂	63	Jejunal ulcer	Subtotal gastric resection	M.S. 8.0 Scop. 0.3 Pento. 100.0	150	390	Third dorsal	2	25
19	J. H.	♂	56	Carcinoma of the stomach	Subtotal gastrectomy	M.S. 10.0 A.S. 0.6 E.S. 50.0	150	550	Third dorsal	3	50
20	M. E.	♀	53	Carcinoma of the stomach	Exploratory laparotomy and biopsy	M.S. 10.0 A.S. 0.4 E.S. 50.0	150	180	Third dorsal	1	..
21	F. M.	♂	45	Gastric ulcer	Subtotal gastrectomy	M.S. 10.0 A.S. 0.6 E.S. 50.0	150	450	Third dorsal	2	35
22	C. D.	♂	31	Duodenal ulcer	Second stage gastric resection	M.S. 10.0 A.S. 0.6 E.S. 50.0	200	420	Third dorsal	2	15
23	J. M.	♂	68	Aneurysm of common femoral artery	Excision of aneurysm	M.S. 10.0 A.S. 0.6 E.S. 50.0	125	200	Sixth dorsal	1	10
24	M. F.	♂	62	Carcinoma of splenic flexure	Resection of splenic flexure	M.S. 8.0 A.S. 10.0 Pento. 100.0 E.S. 75.0	125	250	Fourth dorsal	2	..
25	F. D.	♂	72	Carcinoma of rectum	Combined abdominal perineal resection	M.S. 8.0 A.S. 0.6 E.S. 50.0	150	555	Sixth dorsal	6	35
26	M. B.	♂	42	Intestinal obstruction	Plication of cecum	M.S. 10.0 A.S. 0.6 Pento. 100.0 E.S. 50.0	150	185	Third dorsal	1	..
27	E. S.	♂	63	Aneurysm of left femoral artery	Excision of aneurysm and repair of inguinal hernia	M.S. 8.0 A.S. 0.4 E.S. 25.0	100	165	Fifth dorsal	1	40

* M.S. indicates morphine sulfate; A.S., atropine sulfate; E.S., ephedrine sulfate; Pento., pentobarbital sodium; Scop., scopolamine hydrobromide, and P.S., phenobarbital sodium.

Method in the First Twenty-Seven Consecutive Cases

Intravenous Therapy †	Pentothal Sodium, Gm.	Adrenergic Drug ‡	Operative Complications	Postoperative Complications	Comments
5% D. in W.	....	.....	.....	.....	Patient had 6 major abdominal operations previously for recurrent intestinal polyposis and its complications
5% D. in S.	....	Pit. 5 units E.S. 25 mg.	Moderate fall in blood pressure; slight nausea	Moderate nausea and emesis on first postoperative day	Patient had a previous combined abdominal perineal resection; moderate anemia (R. C. 3,750,000); for maintenance of anesthesia 0.3% instead of 0.5% procaine hydrochloride was used
5% D. in S.	....	.....	.....	.....	After 1 hr. 25 min. of anesthesia, relaxation became poor; administration of 120 drops (6 cc. = 30 mg.) of 0.5% procaine hydrochloride solution within 1 min. resulted in complete relaxation
.....	....	.....	.....	.....	
5% D. in S. + 500 cc. blood	1.0	.....	.....	.....	Besides the usual 8 drops of 0.5% procaine hydrochloride per minute, the patient four times received 100 drops (5 cc. = 25 mg.) of same solution dropped in rapidly
.....	0.6	Pit. 5 units E.S. 25 mg.	Moderate fall in blood pressure after 20 min.	.....	
500 cc. blood	....	.....	.....	.....	
.....	....	.....	.....	.....	
5% D. in W.	....	.....	.....	.....	
.....	....	.....	.....	Nausea and vomiting on operative day	
.....	....	.....	.....	Nausea on operative day	
5% D. in W.	0.55	3 mg. Neo. intramuscularly twice	Fall in blood pressure	.....	
500 cc. blood	1.7	.....	.....	.....	
500 cc. blood	1.4	.....	.....	.....	
500 cc. blood	0.4	.....	.....	.....	After 1 hr. 40 min. of anesthesia 100 drops (5 cc. = 25 mg.) of 0.5% procaine hydrochloride solution was administered for inadequate relaxation
5% D. in S.	....	Pit. 5 units E.S. 25 mg. intramuscularly	Fall in blood pressure	.....	
500 cc. blood	....	Pit. 5 units E.S. 25 mg. intramuscularly	Fall in blood pressure	.....	
500 cc. blood	1.1	.....	.....	.....	
1,000 cc. blood	....	Pit. 5 units E.S. 25 mg. intramuscularly twice	Fall in blood pressure	.....	
500 cc. blood	....	.....	.....	.....	
500 cc. blood	0.75	.....	.....	.....	
N.S.	0.8	.....	.....	.....	Patient was 6 ft. 3 in. (1.9 m.) tall, and initial dose had to be increased to 200 mg. to obtain satisfactory height of anesthesia
500 cc. blood	....	.....	.....	.....	
500 cc. blood	....	.....	.....	.....	Patient was extremely obese, had been operated on previously for carcinoma of uterus and was anemic; blood pressure at start was 80/55 mm. Hg
2,500 cc. blood + 500 cc. plasma	1.25	Pit. 5 units E.S. 25 mg. intramuscularly Neo. 1 mg. intravenously twice	Fall in blood pressure; severe loss of blood	Nausea and vomiting on operative and first postoperative day	Before turning patient to Sims position 6 mg. of tetracaine hydrochloride in 2 cc. of 2.5 D. in S. was given and the spinal needle removed
N.S.	0.3	Neo. 1 mg. intravenously twice	Fall in blood pressure	.....	
N.S. + 300 cc. blood	....	Pit. 5 units E.S. 25 mg. subcutaneously	Fall in blood pressure	Chill attributed to transfusion	Anesthesia maintained with 0.3% procaine hydrochloride solution

† D. in W. indicates dextrose in water; D. in S., dextrose in saline solution and N.S., isotonic solution of sodium chloride.
‡ Pit. indicates pitressin and Neo., neo-synephrine hydrochloride.

COMMENT

With any method involving fractional dosage, the concentration of the anesthetic drug in the spinal fluid is higher immediately after injection of each dose and gradually decreases until the next dose is given. Corresponding to this, the level of analgesia advances and recedes. By the continuous drop method, after the analgesia is established at the desired height, it can be kept there constantly by administering a dilute solution at a suitable rate.

Accidents and undesirable side effects occurring in the course of spinal analgesia are directly related to: (*a*) the inherent toxicity of the drug used; (*b*) the size of the individual dose, and (*c*) the concentration of the drug in the injected solution. The first factor can be reduced to a minimum by using the least toxic local anesthetic available. At the present time pharmacologists are agreed that this agent is procaine hydrochloride. The size of each dose can be reduced with any method of fractional administration, but with such a method each dose must be large enough to produce a concentration at the uppermost anesthetized segment sufficient to produce an analgesia that will last until the next dose. With a more sensitive method, such as the continuous drop technic, after the necessary level of analgesia is established by the initial dose it is possible to add only that amount of the drug necessary to maintain this level from moment to moment. This keeps the concentration of the drug in the spinal fluid at a minimum at all times.

By no means the least important advantage of the drop method is that it provides a perfectly aseptic technic. After it is once connected, the system can be kept closed at all times, there being no necessity for changing a syringe or undertaking other manipulations.

The volume of 0.5 per cent procaine hydrochloride solution injected in the course of an operation varies between 15 and 25 cc. in an hour. It was thought possible that this might result in a serious rise in the pressure of the spinal fluid in operations lasting two hours or more. For this reason a spinal fluid manometer was included in the system in 8 early cases, and readings were taken initially and every ten minutes throughout. A slight gradual sustained rise was observed, which caused no symptoms and was without clinical significance.

Although the apparatus for continuous drop spinal anesthesia can be adjusted to maintain analgesia with little supervision, the safety of the technic depends on its meticulous application and on expert observation and management of the patient. We therefore advise that it be used only by the experienced spinal anesthetist who can give it his undivided attention. It should not be initiated by the surgeon for later supervision by a nurse anesthetist or an intern.

SUMMARY

A continuous drop method for maintaining spinal analgesia is described. The advantages of such a technic are:

1. The level of analgesia can be kept constant.
2. The safety factor is increased because the size of the dose and the concentration of the drug in the spinal fluid can be kept at a minimum.
3. Continuous administration makes it possible to use the least toxic drug.
4. Complete asepsis may be assured.

PENICILLIN IN THE TREATMENT OF CHRONIC OSTEOMYELITIS

A REPORT OF FORTY CASES

DONALD G. ANDERSON, M.D.; LOUIS G. HOWARD, M.D., AND CHARLES H. RAMMELKAMP, M.D.

BOSTON

It is now generally accepted that penicillin is the most effective chemotherapeutic agent yet discovered for the treatment of staphylococcic infections. In view of this fact, a critical study of its action on chronic osteomyelitis should be of value.

Such a study should have two aims: one to evaluate the effectiveness of penicillin for this disease and the other to determine, if possible, the most satisfactory method of employing this new therapeutic agent. In any study of chronic osteomyelitis, prolonged observation of patients after the completion of treatment is necessary before final conclusions can be established.

Several reports have now been published in which reference has been made to the use of penicillin for chronic osteomyelitis.[1] These reports have been concerned chiefly with a description of the immediate effect of penicillin. There has been no report as yet of a series of cases in which it has been possible to follow the course of the disease for any considerable time after the completion of treatment.

From the Robert Dawson Evans Memorial of the Massachusetts Memorial Hospitals and the Departments of Medicine and Orthopedic Surgery, Boston University School of Medicine.

The penicillin was provided by the Office of Scientific Research and Development from supplies assigned by the Committee on Medical Research for clinical investigations recommended by the Committee on Chemotherapeutics and Other Agents of the National Research Council.

1. Florey, M. E., and Florey, H. W.: General and Local Administration of Penicillin, Lancet **1**:388 (March 27) 1943. Keefer, C. S.; Blake, F. G.; Marshall, E. K., Jr.; Lockwood, J. S., and Wood, W. B., Jr.: Penicillin in the Treatment of Infections, J. A. M. A. **122**:1217 (Aug. 28) 1943. Lyons, C.: Penicillin Therapy of Surgical Infections in the U. S. Army, ibid. **123**:1007 (Dec. 18) 1943. Robertson, I. M.: Penicillin in Bone Infections, Brit. M. J. **1**: 519 (April 15) 1944. Mowlem, R.: Surgery and Penicillin in Mandibular Infections, ibid. **1**:517 (April 15) 1944. Dawson, M. H., and Hobby, G. L.: The Clinical Use of Penicillin, J. A. M. A. **124**:611 (March 4) 1944. Barr, J. S.: The Use of Penicillin in the Navy, J. Bone & Joint Surg. **26**:380 (April) 1944. Ferrer, J. M., Jr.: The Role of Penicillin in the Management of Infection, ibid. **26**:522 (July) 1944.

The purpose of this paper is to present a preliminary report of a series of 40 cases of chronic osteomyelitis in which treatment with penicillin has been employed. In 25 of these cases, it has been possible to conduct follow-up observations for one year or longer after completion of the first course of treatment with penicillin. The results of treatment will be presented, and the methods of treatment which we have found to be most satisfactory will be discussed.

CLINICAL MATERIAL

The pertinent data concerning the history, treatment and results of treatment in each case are summarized in table 1.

The patients ranged in age from 14 to 74 years. Thirty-four (85 per cent) were over 20 years of age. The duration of the osteomyelitis varied from two months to forty-nine years. In all but 6 cases it was of more than one year, and in 17 it was of more than ten years. At the time treatment with penicillin was begun, symptoms and signs of active infection had been present for from one week to eighteen years. In 19 cases (47 per cent) draining sinuses had been present for one year or longer.

Most of the patients had received intensive therapy with sulfonamide drugs without benefit, and many of them had had recent surgical treatment. One half of the patients had definite constitutional symptoms, such as fever, malaise and anorexia.

The site of infection was the femur in 25 cases, the humerus in 4, the tibia in 4, the sacrum in 2, the radius in 2 and in 1 each the ulna, the metatarsal bones and the vertebrae. In 35 cases, draining sinuses were present. In the other 5 abscesses of the bone or soft tissues which had not drained were present.

Staphylococcus aureus was cultured from material from the local lesion in all but 2 cases. In 2 cases (cases 31 and 36) abscesses were not drained until penicillin had been given for several days. Material taken for culture at the time of operation was sterile. In each of these

instances Staph. aureus had been cultured from material from the lesion during a previous exacerbation.

In 6 cases (cases 2, 23, 25, 27, 29 and 33) beta hemolytic streptococci were also cultured, isolated from patients before treatment with penicillin was begun (table 2). The tests were performed by the method described by one of us elsewhere.[2] Twenty-four strains were completely inhibited by concentrations of 0.08 Oxford unit in 1 cc. of medium or less. For the other eight strains slighlty higher concentrations of penicillin were necessary to effect complete inhibition, but none of the strains isolated before

TABLE 1.—*Pertinent Data on Forty Cases of Chronic Osteomyelitis in Which Treatment with Penicillin Was Used*

		History				Treatment					Results		
						Duration, Days		Average Daily Dose, Oxford Units					
Case	Age, Yr.	Bone Involved	Duration of Osteomyelitis, Yr.	Duration of Drainage, Wk.	Sequestrums	Systemic	Local	Systemic	Local	Surgical Treatment	Cultures Sterile, Days	Sinuses Healed, Days	Follow-Up Observations
1	36	Femur	23	2	+	28	0	30,000	0	0	17	42	Well at 21 mo.
2	26	Fourth and fifth lumbar vertebrae	1	52	0	6	5	90,000	2,000	0	3	11	Well at 20 mo.
3	44	Femur	32	52	0	16	0	75,000	0	0	9	20	Well at 14 mo.
4	53	Femur	13	1†	0	21	0	120,000	0	0	7	12	Well at 4 mo.
5	58	Femur	25	20	0	14	0	100,000	0	0	5	7	Well at 11 mo.
6	27	Sacrum	3	104	0	20	15	70,000	4,000	0	11	41	Well at 16 mo.
7	37	Femur	29	2	0	23	0	200,000	0	0	17	26	Well at 3 mo.
8	35	Humerus	2	104	0	15	0	120,000	0	0	?	14	Well at 5 mo.
9	27	Femur	14	2	0	13	0	75,000	0	0	17	31	Relapsed at 15 mo.§
10	41	Femur	7 mo.	28	+	19	0	100,000	0	0	14	15	Relapsed at 2 mo.§
11	27	Femur	12	5	+	25	0	110,000	0	0	Never‡	58	Relapsed at 6 mo.§
12	58	Femur	49	104	+	17	0	80,000	0	0	11	45	Relapsed at 3 mo.
13	36	Tibia	10	40	0	24	7	75,000	500	0	21	Never	Failure
14	23	Humerus	5	260	+	25	0	100,000	0	0	Never‡	Never	Failure
15	24	Femur*	16	1	0	2	0	360,000	0	0	Never	Never	Died
16	45	Femur	6	2	0	18	0	75,000	0	0	13	17	Relapsed at 4 mo.
		2d course*	..	2	0	25	0	120,000	0	0	?	14	Well at 11 mo.
17	35	Femur	8	26	+	22	0	100,000	0	0	14	39	Relapsed at 3 mo.
		2d course	..	2	+	24	0	100,000	0	0	5	28	Relapsed at 4 mo.
18	53	Femur	2	6†	0	16	0	75,000	0	0	?	20	Relapsed at 7 mo.
		2d course*	..	2†	0	16	0	120,000	0	0	?	16	Well at 9 mo.
19	36	Tibia	1½	68	0	16	0	60,000	0	0	11	30	Relapsed at 2 mo.
20	21	Femur	7	364	0	23	0	70,000	0	0	11	Never	Improved
		2d course*	..	404	0	55	0	120,000	0	0	14	Never	Improved
21	31	Femur	8	34	0	6	0	65,000	0	0	4	24	Relapsed at 4 mo.
		2d course	..	2	0	15	0	100,000	0	0	16	35	Relapsed at 12 mo.§
22	17	Femur	5 mo.	20	+	56	14	30,000	4,000	0	Never‡	Never	Failure
23	47	Femur	41	520	+	20	3	30,000	3,000	0	Never‡	Never	Failure
24	32	Femur	11	78	+	14	0	30,000	0	0	8	16	Relapsed at 1 mo.
25	60	Sacrum	3	156	+	55	0	90,000	0	0	Never	Never	Improved
26	47	Tibia	33	52	+	6	0	70,000	0	0	4	23	Relapsed at 1 mo.
		2d course	..	0	0	11	0	80,000	0	0	?	7	Well at 9 mo.
27	16	Femur	5	260	+	25	0	75,000	0	0	Never	21	Relapsed at 6 mo.
		2d course	..	2	+	31	10	120,000	20,000	+	Never	28	Well at 6 mo.
28	58	Femur	3	104	0	21	0	30,000	0	0	14	34	Relapsed at 6 mo.
		2d course	..	1	0	29	10	60,000	40,000	+	10	56	Well at 16 mo.
29	36	Femur	24	90	+	20	7	50,000	30,000	+	8	15	Well at 17 mo.
30	14	Femur	4 mo.	16	+	17	12	60,000	10,000	+	10	23	Well at 17 mo.
31	15	Femur	4	4†	0	44	8	80,000	50,000	+	?	44	Well at 10 mo.
32	28	Ulna	21	6†	0	36	10	100,000	15,000	+	3	42	Well at 9 mo.
33	42	Femur	7	364	+	27	9	120,000	20,000	+	Never	33	Well at 4 mo.
34	74	Metatarsus	2 mo.	8	+	31	10	120,000	10,000	+	15	36	Well at 3 mo.
35	14	Humerus	2 mo.	6	+	26	11	120,000	20,000	+	20	33	Well at 5 mo.
36	22	Radius	4	16†	0	26	10	120,000	10,000	+	?	26	Well at 3 mo.
37	29	Humerus	26	312	+	28	10	120,000	20,000	+	8	31	Well at 3 mo.
38	15	Radius	2	1	+	9	14	50,000	4,000	+	?	24	Relapsed at 12 mo.§
39	33	Femur	18	18 yr.	+	29	0	120,000	0	+	Never	25	Relapsed at 1 mo.
		2d course	..	2	+	40	16	200,000	40,000	+	34	41	Well at 2 mo.
40	51	Tibia	5 mo.	12	+	29	10	200,000	30,000	+	Never‡	Never	Failure

* A blood culture was positive for Staph. aureus at the beginning of treatment.
† The figure refers to the duration of symptoms from an undrained abscess.
‡ The organism became resistant to penicillin.
§ The lesion healed spontaneously shortly after the relapse; it was healed at the time of writing.

and in 6 cases (cases 9, 19, 22, 23, 25 and 33) various gram-negative bacilli were present in addition to staphylococci. When the patients first presented themselves for treatment with penicillin only 1 (case 15) had bacteremia.

It was possible to test the susceptibility to penicillin of thirty-two strains of Staph. aureus

2. Rammelkamp, C. H., and Maxon, T.: Resistance of Staphylococcus Aureus to the Action of Penicillin, Proc. Soc. Exper. Biol. & Med. **51**:386 (Dec.) 1942.

treatment was resistant to the action of penicillin.

TABLE 2.—*Susceptibility to Penicillin of Thirty-Two Strains of Staph. Aureus Isolated from Patients with Chronic Osteomyelitis Before Treatment with Penicillin*

Minimal Concentration of Penicillin Completely Inhibiting Growth (Oxford Units in 1 Cc. of Medium)	Number of Strains
0.01	2
0.02	4
0.04	6
0.08	12
0.17	7
0.35	1
Total	32

TREATMENT

In 31 of the 40 cases included in this study, only one course of penicillin therapy was given, while in 9 penicillin was given on two separate occasions. We shall consider first the initial course of penicillin therapy. Later we shall analyze the results of the second course in the 9 cases in which additional treatment was given.

First Course of Treatment.—All the patients received penicillin by intravenous or intramuscular injections at intervals of three or four hours. A few received a portion of the penicillin by continuous intravenous infusion.

In our experience the use of penicillin locally without simultaneous parenteral administration has been ineffective in the treatment of chronic osteomyelitis. After trying it without success in a few cases, we abandoned it. When it is used in conjunction with systemic therapy, however, local administration of penicillin may offer certain advantages.

TABLE 3.—*Total Dose of Penicillin Administered During the First Course of Treatment*

No. of Units *	No. of Cases	Per Cent
500,000	9	60
1,000,000	6	
1,500,000	9	
2,000,000	2	40
2,500,000	4	
3,000,000	5	
3,500,000	2	
4,500,000	1	
5,000,000	1	
5,500,000	1	

* The dose has been computed to the nearest 500,000 units.

Owing to variations in the availability of penicillin throughout the period of study, the dosage of penicillin and the duration of treatment varied considerably. During the early months small doses and short courses of treatment were given. Later, as the supply of penicillin became more plentiful, the dose was increased and the period of treatment was lengthened.

In this study the total dose of penicillin ranged from 400,000 to 5,500,000 units. In table 3 the cases are grouped according to the total dose administered. In 24 cases (60 per cent) the total dose was between 400,000 and 1,500,000 units, while in the other 16 cases (40 per cent) it was 2,000,000 units or more.

The duration of treatment varied from two to fifty-six days. In table 4 the cases are grouped according to the number of days that systemic penicillin therapy was given. In 30 cases (75 per cent) the duration of treatment was between fourteen and thirty-two days.

Penicillin was applied locally in conjunction with systemic treatment in 16 cases (table 1). The total dose administered locally varied from 3,000 to 400,000 units. The period of local administration ranged from three to fifteen days.

TABLE 4.—*Duration of Penicillin Therapy During the First Course of Treatment*

Days	No. of Cases	Per Cent	Days	No. of Cases	Per Cent
2	1	15	22	2	37.5
6	3		24	5	
8	1		26	3	
12	1		28	4	
			32	1	
14	2	37.5	36	1	10
16	6		42	1	
18	2		54	1	
20	5		56	1	

The original object of this study was to observe the effect of penicillin alone in the management of chronic osteomyelitis. Early it was realized that when sequestrums were present or when there was evidence of an undrained intramedullary abscess surgical intervention was advisable. Operation was performed concomitantly with the administration of penicillin in 12 cases. In 8 cases (cases 29, 30, 33, 34, 35, 37, 38 and 40), sequestrectomy was performed; in 3 (cases 31, 32 and 36), a window was made in the cortex and an intramedullary abscess drained, and in 1 case (case 39), in which technical difficulties made it impossible to remove a sequestrum, partial excision of the sinus tract only was carried out. In the cases in which operation was performed, penicillin was administered systemically for several days before operation, in order to reduce acute inflammation and to diminish the possibility of a spread of the infection following operation.

Before operation special attention was directed toward obtaining roentgenograms which would locate accurately osteomyelitic cavities and sequestrums. To accomplish this purpose it was necessary to have films taken from several angles. Roentgenograms taken immediately after the injection of iodized poppyseed oil into the sinus tracts proved to be of great value in determining the extent of sinus tracts and the relation of

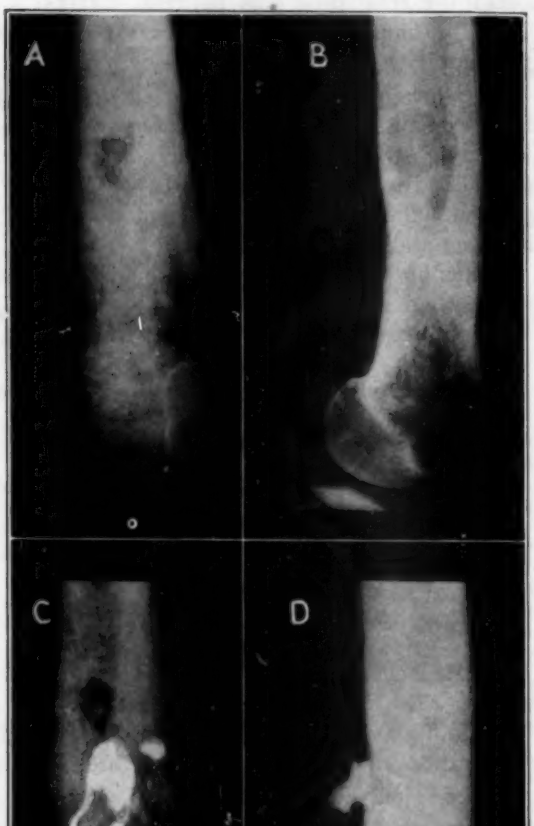

Fig. 1 (case 39).—*A*, anteroposterior view of the right femur; *B*, lateral view; *C* and *D*, same views after instillation of iodized poppyseed oil into the sinus tract, which led to the osteomyelitic cavity containing a sequestrum and also to the sequestrum in the popliteal space. During the first course of penicillin therapy the sinus tract was only partially excised. Relapse occurred after one month. With the second course of penicillin therapy both sequestrums were removed, and the incision has remained healed for two months.

osteomyelitic cavities or sequestrums to these tracts (figs. 1 and 2). Often such films demonstrated that a sinus tract that could be probed for only a short distance actually led, by a tortuous route, to a cavity or a sequestrum which was a considerable distance from the opening of the sinus. So helpful, in fact, was this procedure in demonstrating accurately the focus of active infection that it is now being used in every case in which surgical intervention is contemplated.

Additional information regarding the ramification of sinus tracts was obtained by injecting the tracts with methylthionine chloride (methylene blue) at the beginning of an operation. Occasionally this led to the discovery of sequestrums which were too small to be recognized on roentgenograms.

In carrying out surgical procedures the following considerations were kept in mind. Since sequestrums have no blood supply, penicillin from the blood stream reaches bacteria present in sequestrums with difficulty. Osteomyelitic cavities within sclerosed bone, although partially vascularized, present a similar problem, since penicillin will not diffuse into such areas from the blood stream in adequate concentration. Local circulation is also impaired in soft tissue scars and sinus tracts. Bacteria encysted in such tissue are protected from penicillin and may serve as a focus for a recrudescence of the infection at a later date. Furthermore, scar tissue may harbor sequestrums which are too small or of too light a density to show in roentgenograms.

As a result of these considerations, the following general program was observed for all patients who were subjected to surgical treatment. All sinus tracts and all scar and granulation tissue were excised as far as it was possible and safe to do so. All osteomyelitic cavities that were suspected of being the site of active infection were exposed and thoroughly curetted. A window of sufficient size to permit thorough curettage was made in the bone, but the cavities were not saucerized.

The decision not to saucerize cavities was made after we had observed healing taking place in several patients with cavities following the use of penicillin alone (fig. 3). This observation encouraged us to believe that if the infection could be eradicated by penicillin and cavities made to fill with sterile granulation tissue, no obstacle to satisfactory and lasting healing would exist. The crucial point appeared to be whether cavities could be sterilized. It was recognized that if reliance were placed entirely on systemic administration of penicillin it frequently might not be possible to achieve sterilization. On the other hand, it was felt that if systemic administration were supplemented by local instillation of con-

centrated solutions of penicillin, as will be described subsequently, the chances of sterilizing cavities would be extraordinarily good. Finally, we were anxious to determine whether it was possible to avoid the destruction of healthy bone, a procedure that inevitably increases the amount of repair of bone necessary for final healing.

possible to maintain a constant high concentration of penicillin at the site where it was most needed. In a few cases needles used for inducing continuous spinal anesthesia were employed instead of the rubber catheters. They proved to be much more awkward to manipulate and so were not used after a few trials.

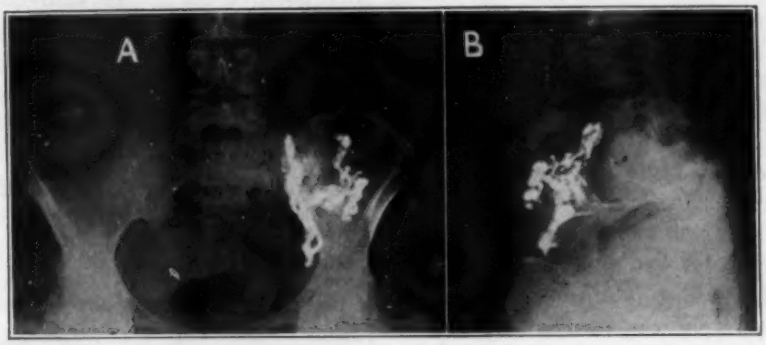

Fig. 2 (case 6).—Anteroposterior view (*A*) and lateral view (*B*) of the pelvis after instillation of iodized poppyseed oil into the sinus tract. The patient had had osteomyelitis of the sacrum for three years. Because of the extent and location of the abscess, surgical treatment was not attempted. After intramuscular administration of 70,000 units of penicillin daily for twenty days and local instillation of 4,000 units daily for fifteen days, the sinus healed and has remained healed for sixteen months.

When the window had been made sufficiently large, the edges of the bone were made smooth and a careful attempt was made to remove all bone sand and chips resulting from the surgical procedure. After the exposure had been completed, the cavity curetted, scar and granulation tissue excised and sequestrums removed, the wound was gently irrigated with copious quantities of warm isotonic solution of sodium chloride. A suction apparatus was employed to remove the fluid and whatever fine particles of bone sand remained. One or more fine soft rubber catheters were then implanted within the bone cavity and sutured to the skin. The wound was closed in anatomic layers, with the use of as little surgical gut suture material as possible below the skin. The cutaneous edges were accurately apposed with fine steel wire interrupted sutures. Steel wire was used because it produces less reaction in the presence of infection than does either cotton or silk. No drains were inserted.

A large, bulky, soft sterile dressing was applied. The ends of the catheters were led out through the main dressing and were covered with a superficial sterile dressing. At the completion of the dressing 1 to 5 cc. of penicillin solution was injected into the catheter, the free end of which was then clamped.

This surgical procedure made the operative area a relatively closed system, with penicillin reaching it both from the blood stream and through the catheters. In this fashion it was

Additional doses of penicillin were given through the catheters every twelve hours. Five thousand units per cubic centimeter of solution

Fig. 3 (case 3).—Anteroposterior view (*A*) and lateral view (*B*) of the left femur, showing an osteomyelitic cavity. No surgical operation was performed. The sinus healed after 75,000 units of penicillin had been administered intramuscularly for sixteen days. The patient has remained well for fourteen months.

was used except in a few cases in which a concentration of 1,000 units was employed. The volume of penicillin solution given by catheter

was gradually reduced, so that by the fifth postoperative day the patient was not receiving more than 1 cc. every twelve hours through any one catheter.

The catheters were generally removed between the seventh and the fourteenth postoperative day, most commonly on the tenth day. The steel wire cutaneous sutures were removed when the incision was well healed, ordinarily between ten and fourteen days after the operation.

Most patients with involvement of a lower extremity were kept at complete rest in bed for one month after the sinus was healed. Patients in whom an upper extremity was involved were usually allowed to get up three to ten days after the operation. These patients as a rule were required to use a sling for one month after the incision was healed.

In this series splinting was used in only 1 case (case 39). In this case a long circular plaster splint was applied after a complete popliteal dissection through massive dense scar tissue had been performed.

No other form of specific chemotherapy was employed. No special diet was given. Patients who were anemic were given 0.2 Gm. of ferrous sulfate four times a day. Three patients received transfusions of whole blood. One patient, who was in shock, received 1,000 cc. of plasma.

Second Course of Treatment.—A second course of penicillin therapy was given to 9 patients who relapsed (table 1). It is of interest that 3 patients had staphylococcic bacteremia at the time of the relapse. The total dose administered during the second course of treatment to 7 of the patients was more than twice that administered during the first course.

Operation was performed in 3 of the 9 cases. In 1 of these (case 39) a sinus tract had been partially excised during the first course of therapy. During the second course sequestrectomy was performed. In the other 2 cases (cases 27 and 28) no surgical operation had been done during the first course of treatment. With the second course of penicillin therapy sequestrectomy was performed in case 27 and simple excision of a sinus tract was carried out in case 28. These last 2 cases brought to 14 (35 per cent) the number in which operative procedures had been performed in conjunction with the administration of penicillin.

RESULTS

There was 1 fatality in this series of 40 cases (case 15). The patient was a 24 year old man who had had chronic osteomyelitis of the femur for sixteen years. He had been in good health for several years until one week before admission to the hospital, when there was a sudden onset of high fever, together with the appearance of a new abscess at the site of an old healed sinus. On admission to the hospital the patient was semicomatose and in shock. The blood culture was positive for Staph. aureus. Despite continuous intravenous infusion of penicillin at the rate of 15,000 units per hour together with administration of plasma and oxygen, he died in less than forty-eight hours. Postmortem examination revealed extensive active osteomyelitis of the upper end of the femur and innumerable septic infarcts of the lungs. This case illustrates well the fact that even massive doses of penicillin will not save a moribund patient.

Except for the patient in this case, all the patients who had constitutional manifestations of an active infection were relieved of their symptoms within a short time after the beginning of penicillin therapy. Almost invariably the appetite improved within seventy-two hours. By the end of the first week there was distinct abatement in pain, fever and malaise. After two weeks these symptoms had disappeared. Several patients who had admitted no constitutional symptoms on entry to the hospital stated that they noticed an increased sense of well-being after seven to ten days of penicillin therapy.

In anemic patients a steady regeneration of hemoglobin was observed, and for patients who had lost weight a gain of 15 to 25 pounds (6.8 to 11.3 Kg.) in the first one or two months after treatment was the usual event.

The effect on the local lesions was equally striking. Usually within five to seven days the signs of acute inflammation disappeared and the discharge was reduced to one quarter or less of the amount that had been present at the beginning of treatment.

After the first week improvement of the local lesions was often slow. Drainage frequently persisted for some time after penicillin therapy was discontinued, but in 27 of the 35 cases in which the lesions were draining on the patient's entry to the hospital, closure of the sinuses occurred in one to eight weeks (average, four weeks) after the beginning of treatment.

The effect on cultures of the blood and of material from the local lesions should be noted. Except in the fatal case, sterile blood cultures were obtained in one to five days in the 4 cases of bacteremia. Cultures of material from the local lesions usually showed a striking decrease in the

number of organisms within three to four days. In 25 cases it became impossible after penicillin had been administered to recover any organisms on repeated culture of material from the local lesions. Material for the cultures was obtained with a fine cotton swab, which was introduced as deeply as possible into a local lesion. The swab was then streaked on a blood agar plate and also inoculated in 5 cc. of veal infusion broth. The blood agar plate was incubated for twenty-four hours and then discarded if no growth had appeared. The broth culture was incubated for seventy-two hours and was then subcultured on blood agar. If the broth remained clear and if no growth was obtained on subculture, the culture was recorded as negative.

The time required to obtain sterile cultures after the beginning of treatment varied from

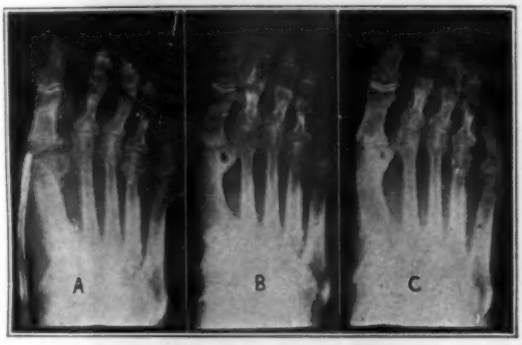

Fig. 4 (case 34).—Anteroposterior views of the right foot, illustrating the rapidity of repair of bone in a 74 year old woman following sequestrectomy and systemic and local administration of penicillin. *A*, nine days postoperatively; *B*, two months postoperatively; *C*, three months postoperatively. This patient also had diabetes mellitus.

three to twenty-one days and averaged eleven days. In most cases sinuses which had once become sterile remained sterile after administration of penicillin was discontinued, until healing took place one or more weeks later. In 4 cases (cases 11, 27, 33 and 39), although the sinuses healed cultures made just before the sinuses closed were still positive for Staph. aureus. No correlation was observed between the results of therapy and the variations in the initial susceptibility of the strains of Staph. aureus in the 32 cases in which this factor was studied.

In 19 cases it was possible to test the susceptibility to penicillin of staphylococci cultured from the local lesions after the patient had received treatment with penicillin for one week or longer. Fourteen strains showed no change in sensitivity to penicillin. In 5 cases (cases 11, 14, 22, 23 and 40) the organisms acquired a definite resistance to the action of penicillin. Before treatment the strains in these cases had been completely inhibited by concentrations of 0.08 Oxford unit in 1 cc. of medium or less. The strains tested after one week or more of treatment required concentrations of 5.7 Oxford units or more in 1 cc. of medium to produce complete inhibition. In 2 of these cases (cases 11 and 14) the sinuses eventually closed. In the other 3 cases they continued to drain. In 2 of these cases (cases 22 and 23) cultures made a year after the completion of penicillin treatment showed that the organisms were still resistant to penicillin.

Changes observed in the roentgenograms after penicillin treatment deserve special comment. The changes were most striking in those cases in which surgical procedures were combined with the use of penicillin. In such cases it was not uncommon to observe over a period of months roentgenographic evidence of rapid healing, with marked decrease in the size of cavities and improvement in the texture of the adjacent bone (figs. 4, 5 and 6). In patients who were treated with penicillin alone and in whom comparative roentgenograms indicated that there had been progressive destruction of bone in the period immediately preceding treatment, evidence of rapid repair was seen.

Evidence of repair and healing in patients who were not operated on and in whom the osteomyelitis had been relatively static for some time was less striking, but in those patients for whom it was possible to take serial roentgenograms over a period of six to twelve months definite signs of improvement were observed in almost every case.

TABLE 5.—*Summary of the Results of the First Course of Treatment*

Result		No. of Cases
Arrested infection		32
Relapsed	15	
Improved		2
Not improved		5
Died		1
Total		40

In table 5 the results of the first course of treatment are summarized. We have classified the condition as arrested in those cases in which all local and constitutional symptoms of infection disappeared and in which all sinuses ceased to

drain and became epithelized. Temporary arrest of the infection was obtained in 32 (80 per cent) cases.

In 2 cases the result was classified as improvement, because although the sinuses never completely healed there was in each instance a striking improvement in both the general condition of the patient and the state of the local lesions.

Fig. 5 (case 35).—Anteroposterior and lateral views of the left humerus, illustrating the rapidity of repair of bone in a 14 year old boy following sequestrectomy and systemic and local administration of penicillin. *A*, before operation; *B*, three weeks postoperatively; *C*, five weeks postoperatively; *D*, ten weeks postoperatively; *E*, fifteen weeks postoperatively.

One of these cases (case 20) deserves special mention. The patient had had chronic osteomyelitis of the right femur and an extensive retroperitoneal abscess (fig. 7) for six years. Physical examination performed on his entry to the hospital revealed the liver to be palpable 8 cm. and the spleen 6 cm. below the costal margin. A congo red test performed prior to treatment showed complete disappearance of the dye from the serum after one hour. After administration of 1,600,000 units of penicillin over twenty-three days, the retroperitoneal abscess healed, although the sinuses in the thigh continued to drain. The patient's general condition was greatly improved, and he was discharged from the hospital. There was no change in the size of the liver or the spleen.

During the next four months the patient gained 50 pounds (22.7 Kg.). At the end of this time the retroperitoneal abscess opened spontaneously. The patient continued to feel well, however, for the next three months, after which drainage from the abscess suddenly ceased. Three weeks later he had a chill, and the temperature rose

to 103 F. He was then readmitted to the hospital. A blood culture made when he reentered the hospital was positive for Staph. aureus. A few hours later the retroperitoneal abscess drained spontaneously. The liver and the spleen had not changed in size since the previous admission. During the next fifty-five days the patient received a total of 6,700,000 units of penicillin. After one week of treatment the temperature became normal. The retroperitoneal abscess healed after five weeks of treatment, as did a sinus on the medial aspect of the right thigh. A sinus on the lateral aspect of the thigh was reduced to the size of a pinpoint but continued to drain despite treatment for another three weeks. A congo red test performed after the patient had been under treatment for six weeks showed that 43 per cent of the dye remained in the serum one hour after injection.

After the patient's discharge from the hospital, he remained well. There was a gradual diminution in the size of the liver and spleen, until eight months after the beginning of the last course of treatment neither organ could be felt.

From the foregoing evidence it seems reasonable to conclude that amyloidosis developed in this patient as the result of the chronic infection and that when the infection was controlled with penicillin there was gradual resorption of the amyloid deposits in the tissues.

In 5 cases there was no improvement, and in 1 death occurred. Failure to improve in 4 cases (cases 14, 22, 23 and 40) resulted from the fact that the patients' organisms became fast to penicillin. In the other case (case 13) there were an ununited fracture of the tibia and an extensive area of exposed and denuded bone in the floor of the sinus. Surgical treatment was refused in this case.

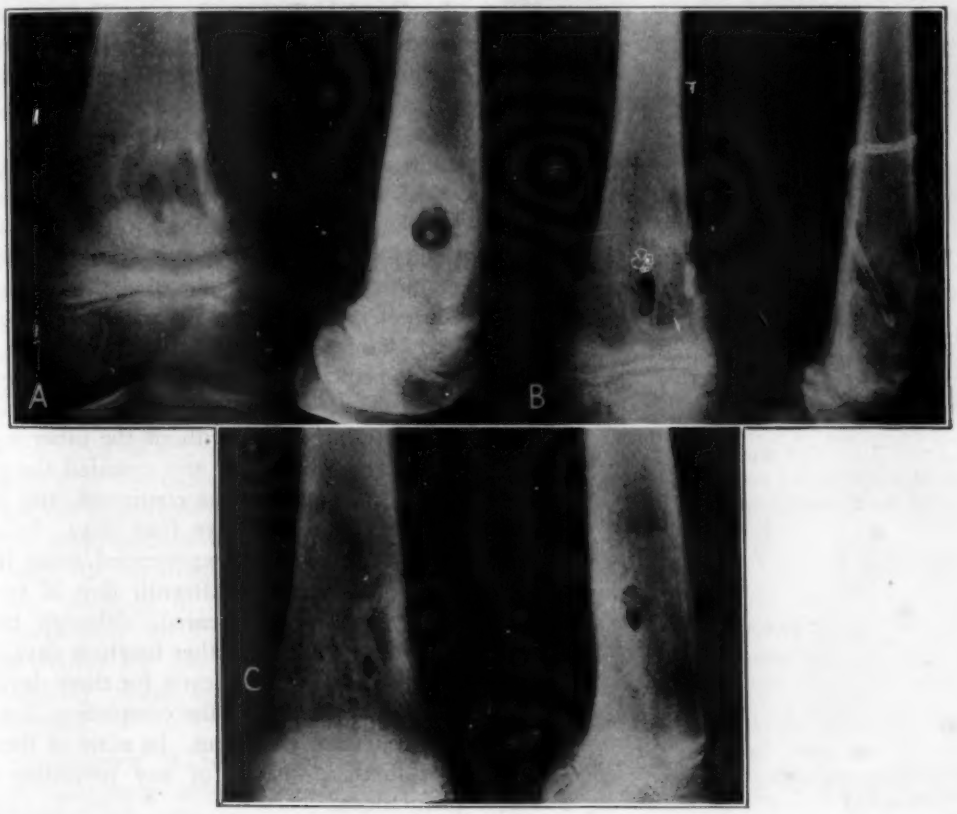

Fig. 6 (case 30).—Anteroposterior and lateral views of the femur, illustrating the extent of repair of bone and the reduction in size of an osteomyelitic cavity thirteen months after sequestrectomy and treatment with penicillin. *A*, before operation; *B*, five days postoperatively; *C*, thirteen months postoperatively.

Of the 32 cases in which arrest of the infection was obtained relapses occurred in 15 (47 per cent). Cultures made after the reappearance of drainage were positive for Staph. aureus in each case. The relapses occurred at intervals of one to fifteen months (average, four and nine-tenths months). In the 17 in which no relapses occurred after one course of treatment, the follow-up period ranged from three to twenty-one months (average, nine and six-tenths months). In 7 of these the patients have remained well for more than a year. Of the 15 cases in which relapses occurred the infection in 4 healed spontaneously

within one to two weeks after the relapse and has remained healed for from four to fourteen months.

In 8 cases, in addition to case 20, a second course of treatment was given, and in each case arrest of the disease was again achieved. In 6 the patients have remained well for an average

Fig. 7 (case 20).—Anteroposterior view of the pelvis after instillation of iodized poppyseed oil, demonstrating the extent of the retroperitoneal abscess.

of nine months, in 1 a relapse occurred at four months and treatment was given again and in 1 a relapse occurred at twelve months but drainage spontaneously ceased within three weeks.

TABLE 6.—*Status of the Patients at the Time of Writing in the Entire Series of Forty Cases* *

Status	No. of Cases
Infection arrested; no relapse	23 †
Spontaneous arrest after relapse	5
Relapse; lesion now draining	4
Improved	2
Not improved	5
Died	1
Total	40

* One course of penicillin therapy was given in 31 cases and two courses in 9.

† These cases include 6 in which relapses occurred after the first course but in which the infection was arrested after the second course of penicillin therapy.

The status of the patients at the time of writing in the entire series of 40 cases is summarized in table 6. In 28 cases (70 per cent) there were no draining sinuses or symptoms of active infection at this time.

TOXIC REACTIONS

One of the most remarkable properties of penicillin has been its lack of significant toxicity. In this series no serious toxic reactions were observed. Minor untoward reactions were observed in 8 cases. Thrombophlebitis developed in 3 cases during constant intravenous infusion of penicillin. In 1 case diarrhea developed. Chills and fever, which were apparently caused by a solution of penicillin that had become contaminated or had deteriorated, occurred in 1. When a fresh solution of the same lot of penicillin was used, no untoward reaction occurred. Urticaria developed in 3 cases. In case 27 urticaria developed on the fourteenth day of the first course of treatment. The urticaria was accompanied by transient fever, sore throat, arthralgia and generalized lymphadenopathy. Administration of penicillin was omitted for nine days, by the end of which time the urticaria had almost entirely subsided. Endermic and conjunctival tests with penicillin showed no reaction, and treatment was resumed for another eleven days. The urticaria did not recur. When the patient received a second course of penicillin treatment eight months later, penicillin from a different manufacturer was used. On the eighth day of treatment urticaria appeared, but without the other signs and symptoms which had accompanied the previous attack. Treatment was continued, and the urticaria disappeared after four days. In case 27 mild urticaria was experienced from the thirteenth through the fifteenth day of treatment. The reaction disappeared, although treatment was continued for another fourteen days. In case 29 there was mild urticaria for three days, beginning eight days after the completion of a twenty day course of treatment. In none of these cases was there a history of any preceding allergic phenomena.

COMMENT

From the experience provided by these 40 cases it can be said that penicillin, by inhibiting the growth and multiplication of bacteria, will arrest the infection in a high percentage of cases of chronic osteomyelitis and thus allow healing of both bone and soft tissue to take place. In only a small percentage of cases does the use of penicillin fail to produce significant improvement.

The specific reasons for failure in those cases in which no improvement was observed have been presented in the preceding section. The chief cause of failure was the development of resistance to penicillin in the infecting organism. The patients whose organisms became resistant were not treated differently from those whose

organisms did not become resistant, and it is not clear how this untoward event can be prevented. It does not appear to be a problem of dosage, since in 3 of the 5 cases in which resistance to penicillin appeared the dose was well above the average for the group. The only measure that we have devised to meet this situation is definitive surgical treatment early, at a time when the organism is still sensitive to penicillin.

While immediate improvement with the disappearance of all signs of infection was observed in 80 per cent of the patients treated, a relatively high incidence of relapses (47 per cent) was encountered. Positive cultures obtained at the time of the relapse indicate that in these instances, at least, penicillin merely suppressed the infection temporarily and did not eradicate it. Of course at this time it is impossible to conclude that viable bacteria may not still be present in those patients who have remained well. A long period of observation will be necessary before it can be determined whether penicillin can permanently eradicate the infection in any case of chronic osteomyelitis.

An analysis of the 15 cases in which relapses occurred should be helpful in disclosing some of the conditions that may lead to early reappearance of the signs of active infection. It is striking that in 9 of the cases demonstrable sequestrums had not been removed. In several of these cases, the reappearance of drainage was associated with the spontaneous extrusion of sequestrums. Relapse in 1 case was definitely related to trauma. In 5 cases no definite cause could be found for the relapse. In all these cases, however, there was massive fibrosis of the soft tissues.

The significance of sequestrums in predisposing to relapses is evident. It is made even more conspicuous by the observation that of the 17 cases in which the patients remained well, in 10 there were no sequestrums and in 6 sequestrums were removed at the time penicillin was administered. In only 1 case (case 1) in which a sequestrum was not removed has the patient remained well (fig. 8).

Including both the first and the second course of treatment, operation was performed in 14 cases. A comparison of the results obtained in the group in which penicillin alone was used with those obtained in the group in which both penicillin and surgical operation were employed is significant (table 7). In only 1 case of the latter group did the incision fail to heal. The patient (case 40) whose organisms became resistant to penicillin was diabetic. In only 2 cases did a relapse occur. In both cases all sequestrums were not removed at operation. In 1 of these cases (case 38), the sinus closed spontaneously after the sequestrum was extruded, while in the other (case 39) the sinus closed after the sequestrum was removed surgically.

Among the 26 cases in which no surgical procedure was performed, death occurred in 1, there was no improvement in 4, improvement was obtained in 2 but the infection persisted and the infection was arrested in 19. In 11 of the 19 relapses occurred. It is clear, from a comparison of the results in these two groups, that if adequate surgical treatment can be carried out in those cases in which it is indicated at the same time that penicillin is administered the chances for securing an arrest of the infection are greatly increased.

Fig. 8 (case 1).—Anteroposterior view of the right femur, showing a sequestrum. This was the only case in which relapse did not occur when a demonstrable sequestrum was not removed.

Primary closure of all operative incisions has been extremely satisfactory. In no case did an untoward reaction result from primary closure. To the time of writing no relapse or failure to improve has occurred as the result of the decision not to saucerize cavities. On the contrary we

have been gratified with the rapidity with which repair of bone has taken place, and the size of the cavities has decreased. Complete saucerization of these cavities would have increased greatiy the time necessary for repair of bone.

TABLE 7.—*A Comparison of the Results Following Treatment with Penicillin Only and Those Following Treatment with Penicillin and Surgical Operation*

	No. of Cases	
Treatment with penicillin only		26
Infection arrested (11 relapsed)	19	
Improved	2	
Not improved	4	
Died	1	
Treatment with penicillin and surgical operation		14
Infection arrested (2 relapsed)	13	
Not improved	1	
Total		40

With chronic osteomyelitis more than one species of bacteria are frequently found when material from the lesions is cultured. In the present series a mixed culture was encountered in 9 cases. In 6 cases one of the secondary organisms was a beta hemolytic streptococcus, an organism which is even more susceptible to penicillin than are the staphylococci. In every case the streptococci disappeared from the cultures before the staphylococci did.

In 6 cases gram-negative bacilli were found on culture. In 3 of these cases (cases 9, 19 and 33), the gram-negative organisms spontaneously disappeared from the cultures after a few days and the sinuses eventually healed. In the other 3 cases the gram-negative organisms persisted. In 1 case (case 25), the presence of gram-negative bacteria may have been responsible for the failure of the sinus to heal. Staphylococci disappeared from cultures while administration of penicillin was continued but reappeared after completion of treatment. In this case, however, striking improvement occurred and a large open wound, 7 by 5 by 3 cm., over the sacrum was converted to a pinpoint sinus. In the other 2 cases (cases 22 and 23), failure to improve resulted from the fact that the infecting staphylococci became resistant to penicillin.

In figure 9 the results of the first course of treatment are plotted against the total dose, computed to the nearest 500,000 units. Good results were obtained with total doses ranging from 500,000 to 3,000,000 units or more. The apparent correlation between the increased dose and the successful results must be questioned when consideration is given to some of the other variables that were present. The group of patients who received the larger dose are those who have been treated most recently and have been followed for the shortest period. In addition, 8 of the 10 patients in this group had operative procedures in conjunction with the administration of penicillin. On only 4 of the 30 patients who received less than 3,000,000 units were surgical procedures performed.

It is our belief, from observing the cases and taking into account the many variables that are present, that a dosage of 15,000 units given intramuscularly every three hours for two to four weeks is effective in most cases. The dosage should be controlled, however, by the response of the lesions and the results of cultures. If there has been no decrease in the amount of drainage and no significant reduction in the number of organisms obtained on culture of material from the local lesions after four to six days of treatment, the advisability of increasing the dose to 25,000 units every three hours should be considered. In view of the lack of toxic reactions following the use of penicillin, doses larger than those recommended here may well prove to be desirable when penicillin becomes available in greater quantities.

In general, patients not requiring surgical operation are treated with penicillin until sterile material has been obtained from the local lesions

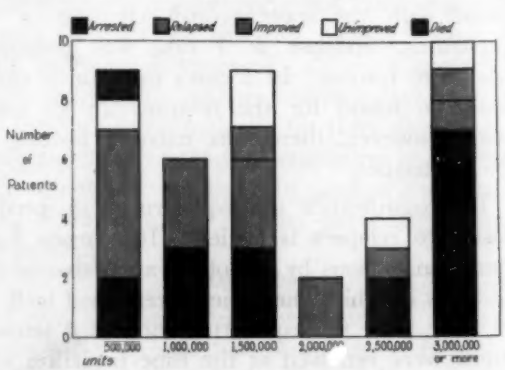

Fig. 9.—Chart correlating the results of the first course of treatment and the total dose of penicillin administered.

for five to ten days. For patients requiring operation, administration of penicillin for four to eight days preoperatively and for ten to twenty days postoperatively is adequate in most instances.

Continuation of treatment until the sinuses are completely healed is apparently not necessary if the material has been sterile for several days. In most of our cases open sinuses persisted

for one or more weeks after completion of treatment and then healed satisfactorily.

Roentgenograms have not been helpful in determining how long to continue treatment. Even in those patients whose roentgenograms show the most rapid improvement, changes appear too slowly to be of any value in guiding treatment.

SUMMARY AND CONCLUSIONS

Penicillin therapy was used in 40 cases of chronic osteomyelitis. Twenty-five of the patients have been observed for a year or longer after treatment.

Operative procedures were combined with the use of penicillin in 14 cases.

At the time of writing, in 28 cases (70 per cent) there are no draining sinuses or other symptoms or signs of active infection.

Primary closure following sequestrectomy or evacuation of an abscess of a bone is a safe and satisfactory procedure for patients who are receiving penicillin.

Miss Marjorie Jewell gave her technical assistance.

PROGRESS IN ORTHOPEDIC SURGERY FOR 1943

A REVIEW PREPARED BY AN EDITORIAL BOARD OF THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

(Continued from page 212)

VII. CONDITIONS INVOLVING THE ELBOW, FOREARM, WRIST AND HAND

PREPARED BY WALTER P. BLOUNT, M.D., MILWAUKEE

The Elbow Joint.—A critical review of 51 wounds involving the elbow joint received in the third Libyan battle in the summer of 1942 is submitted by Buxton.[225] The routine treatment is described, and a statistical study has been prepared, largely from form questionnaires. There was no fracture in only 3 cases. There was great variety in the types of injury to the bone. A primary diagnosis of injury to 14 nerves in 12 patients was made. Paralysis of 2 ulnar nerves was diagnosed later. Of these 16 lesions of nerves, 9 had healed in four months or less. Five had healed in less than seven months, and the end result in 2 was not known. The damage was caused largely by hemorrhage and edema. Many of the nerves recovered their function before the wounds had healed.

In all cases operation was performed more than eleven hours after injury. Suppurative arthritis developed in thirty-one joints. It is the writer's opinion that the suppuration was less and the results better when all loose fragments were removed. This was particularly true after removal of the olecranon, after which a secondary operation was seldom necessary. Primary excision of the joint is rarely indicated in gunshot wounds. In those wounds in which drainage was not adequate following the removal of the loose pieces of bone, posterior drainage was instituted by making 2 wounds, 1 on each side of the olecranon. Fixation was accomplished by plaster of paris, with the elbow at a right angle.

The lessons to be learned from the study are listed:

1. Exercise or actual use of the shoulder and finger joints should be started at once.

2. Active motion of the elbow should not be started until the arthritis is quiescent. Nothing is gained by passive motion.

3. In some elbows with 30 degrees of movement after eight or ten weeks the condition proceeded to a fibrous ankylosis.

4. Some elbows with loss of the olecranon and severe infection regained up to 70 degrees of flexion–extension mobility and half of the supination–pronation movement.

5. Recurrent osteomyelitis and formation of sequestrums are not common sequels of these wounds when the primary operation is well planned.

6. In this series recovery from injury to peripheral nerves without operation was frequent.

A study of the end results was impossible. The anticipated ultimate conditions are listed as follows:

	No. of Cases
Ankylosis	17
Flail elbow	4
Movement greater than 30 degrees	22
Movement less than 30 degrees	5
Amputation	2

Two amputations were performed, because of the extent of the wound. None was required because of suppuration. One death was recorded, of a man with many complicating wounds.

For the reenforcement of flail elbow, Brunner[226] suggests a technic similar to that employed for the knee. It is better to use muscle-activated strips of tendon than free transplants of fascia. The writer suggests stripping up the medial half of the triceps tendon, which is then passed under the elevated ulnar nerve and the flexor carpi ulnaris and the flexor digitorum sublimis muscle, where it is sutured to the periosteum of the ulna. After three weeks of immobilization in a plaster splint, exercises are started, without local heat or massage. No cases are cited, and only diagrammatic drawings accompany the article.

In a girl of 15 years recurrent dislocation of the ulna at the elbow had been present since the age of 3. Recurrence was prevented by Gos-

225. Buxton, S. J. D.: Gunshot Wounds of the Elbow Joint, Lancet **2**:663-665 (Nov. 27) 1943.

226. Brunner, K.: Zur operativen Versorgung des ulnaren Bandschadens am Ellenbogengelenk, Zentralbl. f. Chir. **69**:268-271 (Feb. 14) 1942.

man [227] by driving a bone peg into the coronoid process. The method was similar to that described by Milch. A year after operation there had been no recurrence. Extension was normal, and flexion was somewhat limited. With complete flexion the patient was conscious of the block.

Nine cases of post-traumatic ossifying periarthritis at the elbow are reported by Marottoli and Didier.[228] For the reduction of dislocations complete anesthesia is necessary to afford muscular relaxation. The elbow is fixated for three or four weeks, until there have been healing and resorption of the hematoma. To prevent the deposit of bone the writers emphasize adequate immobilization and avoidance of massage and passive movement. Treatment of existing deposits by immobilization is emphasized. This was sufficient in 2 cases. Roentgen therapy was used in the others. Surgical intervention was necessary in only 1 case, in which the calcified mass was huge. In this case roentgen therapy was used before and after operation. The cases are reported in detail.

Painful paralysis of the arm in small children is described by Feer,[229] in a pediatric journal, as a clinical entity. He reports 39 subluxations of the radial head in 22 children with similar symptoms. Their ages varied from 5 months to 4 years, and the histories were similar. A child was walking holding the hand of the mother. The child fell, and the mother drew the child quickly upward. Immediate pain appeared in the affected arm. The child let the arm hang and protected it carefully. Motion at the elbow joint was impossible. The hand was in pronation. The child was brought to the doctor, who manipulated the forearm into supination. There was a snap, and function was immediately restored. The writer does not use fixation.

Feer notes a high incidence of recurrences, occurring as late as three years and seven months after the initial subluxation. There was no recurrence after five years, and no new dislocation occurred after the age of 5. Relaxation of the ligaments was given as a predisposing cause. Many of the children had rickets. The diagnosis is confusing only if there is a coincident fever. Fracture of the clavicle is mentioned in the differential diagnosis.

227. Gosman, J. A.: Recurrent Dislocation of the Ulna at the Elbow, J. Bone & Joint Surg. **25**:448-449 (April) 1943.

228. Marottoli, O. R., and Didier, A. E.: Las periartritis osificantes del codo, Bol. Soc. de cir. de Rosario **9**:398-412 (Sept.) 1942.

229. Feer, W.: Die schmerzhafte Armlähmung kleiner Kinder, Kinderärztl. Praxis **13**:225-228 (Sept.) 1942.

[Ed. Note.—In his historical discussion the writer confuses "pulled shoulder" with the lesion under discussion. It may be that some of his cases were instances of strained shoulder rather than of true subluxation of the radial head. The two entities are distinct. They should be better known to all orthopedic surgeons. The cause is the same. When the capsule of the shoulder joint is strained, the arm hangs limp and simulates paralysis. The recovery is spontaneous in a few days. A sling is all that is indicated.

In subluxation of the radial head, the arm is held stiffly and somewhat forward, with the hand pronated. The child will move the shoulder and elevate the extremity forward but will not allow any one to touch the hand or forearm. After a word of warning the forearm may be supinated with a quick twist. There is an audible and palpable snap. Pain is relieved and function restored. If there has been delay in reduction, the elbow will be extremely sore. It is well to use a retentive bandage for several days or even longer. Perhaps some of the recurrences which the writer mentions might have been eliminated had he used a retentive dressing or some form of fixation.]

The Wrist.—Gollasch [230] reports a case of osteochondritis dissecans of the wrist in a patient who had had a similar lesion of the elbow on the opposite side. In the course of the examination, crepitation of the wrist called attention to the lesion, although motion was normal. The patient complained of pain after prolonged use. A free body could be palpated just distal to the ulna on the dorsum of the wrist. The source of the free body was not determined.

McGoey [231] reports an injury of the wrist following an impact against the palm and along the axis of the forearm, which caused fracture and dislocation of a congenitally unseparated lunate and triangular bone. There was a fracture of the posterior surface of the anomalous bone, with a dislocation of the carpus posteriorly. Reduction was easily accomplished by simple traction, with the patient under anesthesia. After ten weeks of immobilization the patient resumed use of the wrist. There was a 5 degree limitation of palmar flexion; otherwise recovery was complete at thirteeen weeks.

The Hand.—A classification of kinetic disabilities of the hand is developed by Burman.[232]

230. Gollasch, W.: Osteochondritis dissecans des Handgelenks, Röntgenpraxis **14**:468-469 (Dec.) 1942.

231. McGoey, P. F.: Fracture-Dislocation of a Fused Triangular and Lunate (Congenital), J. Bone & Joint Surg. **25**:928-929 (Oct.) 1943.

232. Burman, M.: Kinetic Disabilities of the Hand and Their Classification, Am. J. Surg. **61**:167-214 (Aug.) 1943.

These comprise mainly the spastic hand, the arthritic hand, the paralytic hand and the traumatized hand. Cases of paralysis contracture and muscular imbalance are included. The various disabilities are analyzed. Conservative and operative treatment is suggested. A detailed discussion with summaries of the cases and a bibliography is furnished.

After examining the roentgenograms of the hands of 1,000 normal infants and 290 abnormal ones, Brailsford [233] gains the impression that separate additional osseous nuclei may develop in the first and the second year of life and fuse before the osseous nuclei for the normal epiphyses appear. In certain dysostoses, other separate additional osseous nuclei develop soon after the diaphysial nuclei, remain without bony union until puberty and then unite with the diaphysis a year or so before the normal epiphyses fuse. He found supplementary epiphyses in only 8.5 per cent of the normal hands. He discusses the appearance of normal and of abnormal epiphyses in congenital deformities, hypothyroidism, craniocleidodysostosis, arachnodactyly, chondrodysplasia and achondroplasia.

Two new cases are reported by Slater and Rubinstein [234] of aplasia of interphalangeal joints associated with synostosis of the carpal and tarsal bones. The skin over the proximal two thirds of the involved fingers is smooth and shows no transverse cutaneous wrinkles. Each finger appears to be composed of two phalanges, an abnormally long proximal one and a small distal one. There is an unusual range of flexion in the terminal phalangeal joint, which serves in a measure to substitute for the lost motion. The hand cannot be closed into a fist, but the persons are little handicapped by their "straight-fingered" hands.

The condition is bilaterally and symmetrically present in the hands and feet. It is hereditary and behaves as a dominant mendelian unit. The rigidity of the fingers results from hypoplasia, rarely aplasia, of the affected joints. There are frequently other associated skeletal anomalies, particularly synostosis of the carpal and tarsal bones.

Pain at the tip of the right index finger called the attention of Staples [235] to an isolated osteochondritis (osteochondrosis) of the osseous center of the distal phalanx in a 4 year old girl. There were redness, tenderness and swelling, without effusion into the distal joint. Motions of the finger were normal. Roentgenograms showed a small, dense epiphysis of the distal phalanx. After two weeks of splinting the local symptoms disappeared. Roentgenograms taken at regular intervals showed improvement of the condition. In five months the epiphysis was entirely normal.

Vogl [236] reports the case of a snapping middle finger of an unusual type. The middle joint of the middle finger was suddenly hyperextended while the patient was pulling on a shoe. After this incident, the middle joint could be flexed only with the assistance of the other hand and then with a snap. Spontaneous attempts to flex the finger at the middle joint resulted in flexion at the distal joint and hyperextension of the middle joint. Roentgenograms disclosed a slight angulation of the middle phalanx of the middle finger with the apex volarward and slightly to the ulnar side. Osteotomy was performed through the base of the middle phalanx to correct the lateral deviation and to produce volar flexion at this joint. The writer says that the snapping stopped and that voluntary flexion was possible. Follow-up roentgenograms showed obvious deformity.

[ED. NOTE.—Post-traumatic hyperextension deformity of the middle joint of a finger probably deserves more attention than it has received. It is an extremely disabling condition. The writer's therapeutic approach seems unwarranted. He substitutes a new deformity for the old, and the finger is still unsightly. At the suggestion of Dr. Stirling Bunnell, one of us (W. P. B.) attacked the same condition by passing fascial grafts through drill holes in the contiguous ends of the bone and thereby efficiently reenforced the palmar capsule. The resulting fingers appear normal, and function is completely restored. This approach would seem more logical than an attack on the bone.]

The principle of intra-articular tenodesis is applied by Slocum [237] to the stabilization of a chronic dislocation of the first metacarpal bone on the multiangular bone. One-half inch (1.3 cm.) distal to the joint a hole was drilled obliquely through the metacarpal bone to the center of the joint to meet a similar hole originating from the dorsolateral aspect of the greater

233. Brailsford, J. F.: Variations in the Ossification of the Bones of the Hand, J. Anat. **77**:170-175 (Jan.) 1943.

234. Slater, P., and Rubinstein, H.: Aplasia of Interphalangeal Joints Associated with Synostoses of Carpal and Tarsal Bones, Quart. Bull., Sea View Hosp. **7**:429-443 (Oct.) 1942.

235. Staples, O. S.: Osteochondritis of the Epiphysis of the Terminal Phalanx of a Finger, J. Bone & Joint Surg. **25**:917-920 (Oct.) 1943.

236. Vogl, A.: Schnellender Finger mit-knöcherner Ursache, Ztschr. f. Orthop. **73**:138-140 (April) 1942.

237. Slocum, D. B.: Stabilization of the Articulation of the Greater Multangular and the First Metacarpal, J. Bone & Joint Surg. **25**:626-630 (July) 1943.

multangular bone. A piece of palmaris longus tendon was threaded through the drill hole, and with the thumb in moderate opposition it was sutured back on itself to form a loop. The joint was stable though freely movable. The remaining length of tendon was plicated across the back of the joint to form a new posterior capsular ligament. A cast was applied for three weeks. In the case reported a 22 year old Negro man obtained a good result after eight months. The patient returned to full duty as a cook in the United States Army.

When operative repair of a "baseball" finger (avulsion of the insertion of the extensor digitorum communis tendon) is necessary, Saypol [238] suggests an interesting addition to the technic. In order to anchor the tendon a needle is passed transversely through the base of the distal phalanx and a thread is drawn through. A transverse dorsal incision is sufficient to permit passage of tiny hooks around the needle on either side of the bone. As the needle is slowly passed through, the suture material is caught and brought out into the wound by the hook. The suture material is passed through the tendon and tied with the finger in hyperextension, holding the tendon or fragments of bone snugly in position. The finger is splinted by malleable metal, with hyperextension of the distal joint and slight flexion of the other joints.

A study of the extensor indicis proprius muscle is offered by three men from Northwestern University Medical School.[239] Two hundred and sixty-three extremities from 140 consecutive cadavers were studied. Forty-one of the 263 (15.6 per cent) showed marked differences in size, origin or insertion of the muscle or in all of these features. In no case was there a total absence. In 8 female cadavers the muscle was extremely small.

The muscle is found only in man, the gorilla and frequently the chimpanzee. In man it normally arises primarily from the ulna and secondarily from the interosseous membrane (75 per cent), the dorsal ulnar septum (58 per cent) or the extensor pollicis longus septum (58 per cent). In 3 cadavers the muscle was abnormal in origin only. Aside from variations in origin, supernumerary tendons were present in a total of 30 cadavers (11.4 per cent). Excellent drawings of anomalous tendons accompany the article.

238. Saypol, G. M.: Technic for the Repair of "Baseball" Finger, Am. J. Surg. **41**:103-104 (July) 1943.

239. Cauldwell, E. W.; Anson, B. J., and Wright, R. R.: The Extensor Indicis Proprius Muscle, Quart. Bull., Northwestern Univ. M. School **17**:267-279, 1943.

VIII. CONDITIONS INVOLVING THE KNEE JOINT

PREPARED BY RALPH K. GHORMLEY, M.D., ROCHESTER, MINN.

Embryology.—McDermott [240] traced the development of the knee joint by means of serial sections from the third week of fetal life to birth, and the meniscuses were studied to the age of 12 years. A thorough review of the embryologic development of the knee joint is included in this article.

Anatomy and Physiology.—Brantigan and Voshell [241] made a detailed gross and microscopic study of the tibial collateral ligament and its environment. They say that this ligament is attached superiorly to the medial femoral epicondyle and inferiorly to two points on the tibia, one posterior, just below the articular cartilage, lateral to and above the insertion of the semimembranous tendon, and the second anterior to the medial tibial surface and 4.6 cm. below the articular surface. There are two divisions of the ligament: (1) anterior parallel fibers from the femur to the tibia and (2) posterior oblique fibers. The anterior fibers have no capsular or meniscal attachments. The posterior fibers blend with the true capsule of the joint, which in turn blends with the posterior portion of the meniscus. The anterior portion is separated from the meniscus by true capsules and often by a true bursa lying in any portion of the ligament. [ED. NOTE.—This article supplements others by these authors, which are of great importance for reviewing the anatomy of the knee.]

Pathologic Conditions of the Knee Joint.—Injuries and Dislocations: Anderson [242] reviews some of the reported cases of dislocation of the knee and adds 4 cases which he has observed. He briefly considers the complications which involve nerves, blood vessels and ligaments and also considers associated fractures. In 1 case open reduction was necessary, and in another case amputation had to be performed because of gangrene. Clarke [243] reports a case

240. McDermott, L. J.: Development of the Human Knee Joint, Arch. Surg. **46**:705-719 (May) 1943.

241. Brantigan, O. C., and Voshell, A. F.: The Tibial Collateral Ligament: Its Function, Its Bursae, and Its Relation to the Medial Meniscus, J. Bone & Joint Surg. **25**:121-131 (Jan.) 1943.

242. Anderson, R. L.: Dislocation of the Knee: Report of Four Cases, Arch. Surg. **46**:598-603 (May) 1943.

243. Clarke, H. O.: Dislocation of the Knee-Joint with Capsular Interposition, Proc. Roy. Soc. Med. **35**: 759 (Oct.) 1942.

in which dislocation of the knee was treated by open reduction. Cubbins, Callahan and Scuderi [244] consider injuries of the ligaments of knee joints caused by dislocation of the knee. The most common injuries of the ligaments are: (1) avulsion of the collateral tibial ligament and (2) rupture or avulsion of one or both cruciate ligaments, accompanied by rupture or avulsion of the collateral tibial and the collateral fibular ligament. Abnormal anteroposterior motion of the tibial plateau on the head of the femur with the knee flexed to 90 degrees, lateral motion of the straight knee and anteroposterior slipping of the tibial plateau on the femoral condyle are evidence of rupture or avulsion of the cruciate ligaments. For injury of the collateral tibial ligament the affected limb was immobilized for eight to ten weeks in complete extension. Recovery has been perfect. Complications of dislocation of the knee joint are injuries of blood vessels and nerves in the popliteal space. Treatment of complications consists of reduction of the dislocation, elevation of the involved limb and application of external heat. If the vascular supply is inadequate, amputation may be necessary.

Peirce and Eaglesham [245] report 8 cases of injury of the knee associated with fracture of the tibia in which lateral roentgenograms, made with the patient in the supine position, disclosed hydrarthrosis.

Pelner [246] reports 4 cases (and 3 control cases) of traumatic hydrarthrosis of the knee joint in which treatment consisted of a diet that was low in sodium chloride and contained acid-producing foods or foods that yielded a neutral ash on combustion. The ingestion of fluids was not limited. He found that an effusion into a joint was removed rapidly by this means, just as edema fluid is removed.

Rupture of Tendons: Gamey [247] reports a case in which an old rupture of the quadriceps tendon was followed by a rupture of the opposite quadriceps tendon. Immediate repair of the last rupture produced a good result, which serves to emphasize the importance of early repair.

244. Cubbins, W. R.; Callahan, J. J., and Scuderi, C. S.: Dislocations of Knee Joint and Their Complications, Indust. Med. **12**:732-733 (Nov.) 1943.

245. Peirce, C. B., and Eaglesham, D. C.: Traumatic Lipohemarthrosis of the Knee, Radiology **39**:655-662 (Dec.) 1942.

246. Pelner, L.: The Rapid Removal of Excess Joint Fluid by Acid Salts: Experiments with Traumatic Hydrarthrosis of the Knee Joint, Am. J. M. Sc. **206**: 498-503 (Oct.) 1943.

247. Graney, C. M.: Bilateral Rupture of Quadriceps Femoris Tendons with Six-Year Interval Between Injuries, Am. J. Surg. **61**:112-116 (July) 1943.

Injury of the Semilunar Cartilages: Childress and Hagen [248] consider the symptoms and signs of injury of the semilunar cartilage and describe their method of treatment. They say that the most reliable sign and symptom are locking of the knee and pain over the involved meniscus. Their technic for removal of a semilunar cartilage is as follows: Without a tourniquet the meniscus is removed with the Lowe-Breck knife and a tonsil snare. An elastic bandage and a plaster cast are applied. The cast is bivalved on the second day, and "quadriceps setting exercises" are begun. Sutures are removed and weight bearing is begun in eight to ten days.

MacAusland [249] reviews 850 cases in which derangement of the knee joint was due to injury to the semilunar cartilages. [ED. NOTE.—This is a thorough report of the subject, and any abstract will not do justice to it. Persons interested in this subject should read the article.]

Caldwell,[250] King,[251] Kellam,[252] Alexander,[253] Peterson and Lille,[254] Terhune, Eddleman, Thompson and Read,[255] Slocum and Moore,[256] MacKenzie and MacFarlane [257] and Hamilton and Finklestein [258] all wrote on the operative treatment of internal derangement of the knee joint in the armed services. Their articles deal particularly though not wholly with injuries of the meniscuses. [ED. NOTE.—The variations in operative technic and in postoperative treatment

248. Childress, H. M., and Hagen, W. H.: Practical Aspects of Diagnosis and Surgical Treatment of Meniscus Injuries, Mil. Surgeon **93**:301-305 (Sept.) 1943.

249. MacAusland, W. R.: A Study of Derangement of Semilunar Cartilages Based on 850 Cases, Surg., Gynec. & Obst. **77**:141-152 (Aug.) 1943.

250. Caldwell, G. D.: Internal Derangement of the Knee Joint, Mil. Surgeon **92**:648-653 (June) 1943.

251. King, B. B.: Knee Joint Arthrotomy in Military Life, Am. J. Surg. **62**:382-386 (Dec.) 1943.

252. Kellam, H. I. J.: Knee Cartilages, abstracted, Glasgow M. J. **138**:5-6 (Dec.) 1942.

253. Alexander, J. C.: Knee Injuries in the Army, Glasgow M. J. **140**:12-15 (July) 1943.

254. Peterson, T. H., and Lille, J. J.: Injuries of the Semilunar Cartilages of the Knee, U. S. Nav. M. Bull. **41**:1336-1338 (Sept.) 1943.

255. Terhune, S. R.; Eddleman, T. S.; Thompson, S. B., and Read, B. S.: The Care of the Knee Following Excision of a Meniscus, J. Bone & Joint Surg. **25**: 663-669 (July) 1943.

256. Slocum, D. B., and Moore, D. E.: Posterior Horn Lesions in Meniscal Injury, Surg., Gynec. & Obst. **77**:87-90 (July) 1943.

257. MacKenzie, D. W., and MacFarlane, J. A.: Internal Derangements of the Knee Joint in the Canadian Army (Overseas), Canad. M. A. J. **49**:472-478 (Dec.) 1943.

258. Hamilton, A. S., and Finklestein, H. E.: The Result of Meniscectomy (Knee Joint) in Soldiers, South. M. J. **36**:406-411 (June) 1943.

are so great as to leave one in doubt as to which regimen is best. It is to be hoped that the various surgeons general may be able to produce a composite picture of the results so that a satisfactory routine may be established.]

Levinthal [259] reviews the anatomy of the knee and gives a classification of the internal and external derangements. Of 600 cases in which operation was performed on the knee, he found lesions of the internal semilunar cartilage in 41 per cent, lesions of the external semilunar cartilage in 6 per cent, lesions of both semilunar cartilages in 2.7 per cent, lesions of the infrapatellar fat pad in 4.7 per cent, osteochondromatosis in 2 per cent and various other conditions in the remainder of the cases. He noted that 50 per cent of the tears of the internal semilunar cartilage were of the bucket handle type.

Moorhead and Lyall [260] report 189 cases in which a similar type of arthrotomy was performed on the knee joint. They advocate a large medial incision. In 77, or 64 per cent, of 121 cases of recent injury of the cartilage there were other abnormalities of sufficient degree to warrant surgical treatment. Most of these defects would not have been seen if small incisions had been made.

Gunshot Injuries.—Buxton [261] considers the treatment of gunshot injuries. In the forward areas of the war zone the leg is immobilized in extension in a Thomas splint. The wound alone is dressed. At the base hospital the joint is aspirated and foreign bodies are removed immediately if the wound is infected. If the wound is not infected two or three weeks is allowed to elapse before the foreign bodies are removed. Early movement is encouraged in cases in which there is no infection. In cases of expected ankylosis, the knee should be kept straight, not hyperextended.

Fridland,[262] in writing on the same subject, says that wounds of the knee joint are divided into two groups: (1) penetrating injuries and (2) periarticular injuries. In periarticular injuries, infection of the joint may develop later than it does in penetrating wounds. In the former the infection spreads along fracture planes. Open wounds are closed in twelve to sixty hours if sulfonamide drugs have been applied to the wound within a few hours. Foreign bodies are removed, and the joint cavity is mopped with 25 to 95 per cent alcohol and liberally treated with sulfonamide drugs in powder form. The synovial membrane is closed with silk sutures, and the wound is packed lightly with dry gauze. A plaster cast is applied from the ankle to the hip. A window is cut over the site of the injury. The packing is removed in twenty-four to forty-eight hours, and the wound is treated with hypertonic solution of sodium chloride if a thick discharge is present or with oily dressings if a thin discharge is present. Early passive movements are recommended, and in three to four weeks the patient is allowed to walk with crutches. Any effusion into the joint is aspirated, and the joint is irrigated with 1 : 500 solution of 2,ethoxy-6,9-diaminoacridinium hydrochloride (rivanol) or with a 3 per cent solution of phenol. In case the temperature remains high after five aspirations, drainage is advocated, with the patient on his side. Secondary resection of the joint is advocated for superficial osteomyelitis. Amputation should not be unduly delayed in cases of advanced sepsis.

Dislocation of the Patella.—Vallinkoski [263] reviews the results of the treatment of recurrent dislocation of the patella with the Krogius operation. He concludes that the results are good in cases of simple recurrent dislocation, but he does not recommend this procedure for the complicated type of dislocation.

Osteochondral Fracture of the Patella.—Milgram [264] describes what he calls "tangential osteochondral fracture" of the patella. He points out that this lesion is a purely traumatic avulsion of the cartilage from the patella and says that it must be distinguished from osteochondritis dissecans.

Flexion Deformities of the Knee.—Kuhns [265] and Reich [266] both review their experience with the correction of flexion deformities of the knee. Both of these articles are good, and it is suggested that they be read by any one desiring information on this subject.

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259. Levinthal, D. H.: Surgery of Derangements of the Knee Joint, S. Clin. North America **23**:181-203 (Feb.) 1943.

260. Moorhead, J. J., and Lyall, D.: The Surgical Treatment of Intrinsic Knee Joint Lesions: Further Analysis of Operative Cases, Ann. Surg. **117**:140-151 (Jan.) 1943.

261. Buxton, S. J. D.: Gunshot Wounds of the Knee Joint, abstracted, Bull. War Med. **3**:506 (May) 1943.

262. Fridland, M. O.: Gunshot Wounds of the Knee-Joint, abstracted, Bull. War Med. **4**:17-18 (Sept.) 1943.

263. Vallinkoski, T. V.: Ueber Behandlungsresultate der sogenannten habituellen Kniescheibenverrenkung mit der Operation von Krogius, Zentralbl. f. Chir. **69**:1232-1234 (July 25) 1942.

264. Milgram, J. E.: Tangential Osteochondral Fracture of the Patella, J. Bone & Joint Surg. **25**:271-280 (April) 1943.

265. Kuhns, J. G.: Treatment of Arthritic Contractures of the Knee, New England J. Med. **227**:975-980 (Dec. 24) 1942.

266. Reich, R. S.: Treatment of Flexion Deformities of the Knee, Surgery **13**:746-754 (May) 1943.

Knock Knees.—Lloyd [267] points out that valgus ankles rather than rickets are the forerunners of knock knees. As a preventive, he advocates corrective shoes, but in cases in which such treatment does not prove satisfactory he advocates the use of a special splint.

Infection.—Bercovitz [268] says that suppurative arthritis of the knee due to Haemophilus influenzae is rather uncommon. This condition primarily affects infants less than 2 years of age and rarely affects adults. Complete recovery is to be expected, whether surgical or expectant treatment is employed.

The author reports a case in which the disease involved the left knee of a Negro girl aged 15 months. The aspirated purulent fluid from the knee produced a pure culture of H. influenzae. Treatment consisted of traction, aspiration, blood transfusion and oral administration of sulfonamide drugs. The patient recovered completely.

Tumors.—Meyerding and VanDemark [269] report 15 cases in which a popliteal cyst was removed. The symptoms were aching, stiffness and consciousness of a mass in the popliteal space. In the differential diagnosis one must consider lipoma, xanthoma, fibrosarcoma, aneurysm, arteriovenous fistula or hemangioma, infectious swelling and Charcot's joint. Haggart [270] made a similar review of 34 cases. A case of synovioma of the knee is reported by Eveleth and Brezina.[271] Harmon [272] and Wallace and Ghormley [273] report cases of hemangioma of the knee. Harmon discusses the diagnosis and the treatment of this condition.

Ghormley and Dockerty [274] report 4 cases in which myxomatous tumors around the knee joint were thoroughly studied grossly and microscopically. They compare these tumors with Baker's cysts. They conclude that cysts of the semilunar cartilage are not true neoplasms but are the end result of degeneration. Such cysts do not contain an endothelial lining and thus differ from Baker's cysts and other cystic lesions that occur about the knee joint.

Roentgenographic Examination.—Cullen and Chance [275] advocate a method of air arthrography, and Somerville [276] reports the use of this method. Clausen [277] describes the use of a contrast medium which consists of a mixture of 10 cc. of a 35 per cent solution of perabrodil (same as skiodan) and 5 cc. of a 0.5 per cent solution of procaine hydrochloride. This contrast medium is not removed from the joint. Möhlmann and Madlener [278] used gas as a contrast medium.

Surgical Procedures.—Cozen [279] suggests a different technic for exposing the medial meniscus of the knee joint. He says that with the patient in a prone position and the knee to be operated on in full flexion better visualization of the posterior portion of the semilunar cartilage is obtained. He has operated on 15 patients by this technic. Mitchell [280] describes a new meniscectomy knife, similar in principle to that of Breck and Lowe and other surgeons. Coonse and Adams [281] describe what they term a "new operative approach to the knee joint." The usual paramesial incision is made. A Y incision with the stem of the Y pointing proximally is made through the quadriceps tendon about 2 inches (5. cm.) above the patella and continuing down and around the patella about ¼ to ½ inch (0.6 to 1.3 cm.) away from it. The patella is retracted downward, and full exposure of the knee joint is afforded. The authors say that the advantage of this approach is that it

267. Lloyd, E. I.: Knock-Knees and Bow-Legs, Practitioner **150**:238-244 (April) 1943.

268. Bercovitz, G. D.: Suppurative Arthritis Due to Bacillus Hemophilus Influenzae, Bull. Hosp. Joint Dis. **4**:41-43 (April) 1943.

269. Meyerding, H. W., and Van Demark, R. E.: Posterior Hernia of Knee (Baker's Cyst, Popliteal Cyst, Semimembranosus Bursitis, Medial Gastrocnemius Bursitis and Popliteal Bursitis), J. A. M. A. **122**:858-861 (July 24) 1943.

270. Haggart, G. E.: Synovial Cysts of the Popliteal Space: Clinical Significance and Treatment, Ann. of Surg. **118**:438-444 (Sept.) 1943.

271. Eveleth, M. S., and Brezina, P. S.: Synovioma Involving Knee Joint: Case Report, Yale J. Biol. & Med. **16**:27-30 (Oct.) 1943.

272. Harmon, P. H.: Hemangioma of the Synovial Membrane of the Knee Joint Cured by Synovectomy, Arch. Surg. **47**:359-363 (Oct.) 1943.

273. Wallace, G. T., and Ghormley, R. K.: Cavernous Hemangioma of Knee, Proc. Staff Meet., Mayo Clin. **18**:177-182 (June 16) 1943.

274. Ghormley, R. K., and Dockerty, M. B.: Cystic Myxomatous Tumors About Knee; Their Relation to Cysts of Menisci, J. Bone & Joint Surg. **25**:306-318 (April) 1943.

275. Cullen, C. H., and Chance, G. Q.: Air Arthrography in Lesions of Semilunar Cartilages, Brit. J. Surg. **30**:241-245 (Jan.) 1943.

276. Somerville, E. W.: Air Arthrography in Diagnosis of Internal Derangement of Knee Joint, Proc. Roy. Soc. Med. **36**:663-664 (Oct.) 1943.

277. Clausen, A.: Question of Positive or Negative Contrast Substances of Knee, Fortschr. a. d. Geb. d. Röntgenstrahlen **65**:76-80 (Feb.) 1942.

278. Möhlmann and Madlener: Using Contrast Substance; Demonstration of Menisci Lesions in Roentgenograms Obtained During Simultaneous Abduction, Adduction and Rotation of the Knee, Fortschr. a. d. Geb. d. Röntgenstrahlen **65**:51-76 (Feb.) 1942.

279. Cozen, L. N.: Prone Position for Exposing Medial Meniscus of Knee Joint, Arch. Surg. **46**:616-618 (May) 1943.

280. Mitchell, A.: Meniscotomy Knife, Lancet **1**:528 (April 24) 1943.

281. Coonse, K., and Adams, J. D.: A New Operative Approach to the Knee Joint, Surg., Gynec. & Obst. **77**:344-347 (Oct.) 1943.

affords adequate exposure of this joint with a minimum of trauma of soft tissue by retraction. [ED. NOTE.—It is my impression that such an extensive incision is not necessary in most procedures on the knee joint.]

Reconstruction of Crucial Ligaments: Albee [282] describes a new operation for repair of the crucial ligaments. Through a split patellar incision the joint, the femoral condyle and the upper part of the tibia are exposed. Holes are drilled through the outer condyle of the femur from an anterior external point to a point in the intercondylar notch and from the anterior portion of the tibia into the intercondylar spines of the tibia. Fascia lata from the thigh is threaded through and wedged into the drill holes with bone plugs. The drill holes are varied in position, according to the type of instability present. Novillo Martinez [283] describes a method of repairing the anterior crucial ligament by passing a strip of fascia lata through the external condyle and the internal tuberosity and fixing it to the neighboring tissues. Perez Zabala [284] reviews several cases in which the anterior crucial ligament was repaired.

282. Albee, F. H.: A New Operation for the Repair of the Crucial Ligaments of the Knee, Am. J. Surg. **60**:349-353 (June) 1943.

283. Novillo Martinez, L.: Reconstruction of Anterior Crossed Ligaments (Groves Technic), Bol. y trab., Soc. de cir. de Córdoba **3**:322-327, 1942.

284. Perez Zabala, M.: Reconstruction of Ligaments of Knee, Bol. d. Inst. clín. quir. **18**:645-661 (Sept.) 1942.

[ED. NOTE.—The frequency with which methods of repair of the anterior crucial ligaments are described emphasizes the unsatisfactory results obtained with these procedures.]

Patellectomy: Urrutia [285] reports 2 cases in which patellectomy was performed. In 1 case it was performed for tuberculosis, and in the other case it was performed for staphylococcic osteitis. Tuberculous arthritis developed in the first case, but a satisfactory functional result was obtained in the second case.

Synovectomy: McKeever [286] advocates the use of cellophane as an interposing membrane in cases in which synovectomy is performed. He reports 4 cases in which this material was used.

Arthrodesis: Hatt [287] states that fusion of the knee by a central graft does not cause arrest of growth, probably because of the mode of growth in length of a bone. As pointed out by Aries, longitudinal growth of bone does not take place in the form of lines parallel to the epiphysial disk but by successive cones from the endosteal surface, each new cone having for its base the peripheral portion of the disk and possessing a wider perimeter than the old. Of 67 cases in which a fusion operation was performed, 44 were studied to evaluate the result on growth of bone.

285. Urrutia U., C.: Patellectomy for Osteitis: Two Cases, Rev. méd. de Chile **71**:675-678 (July) 1943.

286. McKeever, D. C.: The Use of Cellophane as an Interposition Membrane in Synovectomy, J. Bone & Joint Surg. **25**:576-580 (July) 1943.

287. Hatt, R. N.: Central Bone Graft in Joint Arthrodesis, Arch. Surg. **46**:664-665 (May) 1943.

IX. FRACTURES

PREPARED BY WALTER G. STUCK, M.D., SAN ANTONIO, TEXAS; R. BEVERLY RANEY, M.D., DURHAM, N. C.; JOHN J. FAHEY, M.D., CHICAGO; DON H. O'DONOGHUE, M.D., OKLAHOMA CITY, AND HERMAN F. JOHNSON, M.D., OMAHA

In spite of war and confusion, able and numerous articles have been published in the surgical journals on all phases of the treatment of fractures. In 1943 more articles on war wounds, fatigue fractures and devices for external fixation appeared than in former years. We have tried to make a fair appraisal of them and to submit reviews of those we consider most timely. Any oversights are more than likely due to the endless demands on the reviewers in these parlous times.

Fractures of the Face and Jaw.—It is more and more apparent that fractures of the face and jaw require free interchange of opinion among dentists, plastic surgeons and orthopedic surgeons if best results are to be obtained. This is especially true of the more severe crushing and compound injuries.

In a statistical study of 1,149 cases of fracture of the facial bones, Lyons [288] notes these significant facts: Fifty-one of the fractures resulted from automobile accidents, while industrial accidents caused about 32 per cent. Thirty per cent of the fractures involved the maxilla and 70 per cent the mandible. The right side of the face is more vulnerable to fractures than the left side. One of the greatest complications of fractures of the jaw is loss of teeth. It must always be borne in mind that fractures of the skull may coexist with fractures of the facial bones.

Winter [289] reports 50 cases in which he used the Roger Anderson skeletal fixation appliance

288. Lyons, D. C.: Care of Military and Civilian Injuries: Fractures of Mandible, Maxilla, Zygoma, and Other Facial Bones; Statistical Study of 1,149 Cases, Am. J. Orthodontics (Oral Surg. Sect.) **29**:67-76 (Feb.) 1943.

289. Winter, L.: Fractures of the Mandible: Report of Fifty Applications of Roger Anderson Skeletal Fixation Appliance, Am. J. Surg. **61**:367-379 (Sept.) 1943.

for fractures of the mandible. In the article are excellent diagrams of the anatomy of the cheek and jaw and photographs of the equipment used. This device is preferred over all others because it is easy to apply, it produces secure fixation of the fragments without immobilizing the jaw and it simplifies nursing care. There are a few relatively unimportant pitfalls, which are described.

For edentulous jaws, or those with too few teeth, external supports are essential for the proper immobilization of the fractured fragments. Since 1940 Bigelow [290] has developed a method whereby vitallium screws are inserted into the mandible from the outside. At first the screws in the bone were united by a splint of strap iron or dural. Now, however, the screws are fastened to a vitallium alinement bar, which supports the fracture. Sometimes it is preferable to insert a vitallium screw into the jaw and provide traction from it to a plaster head piece. [ED. NOTE (W. G. S.).—An external vitallium bar to connect the vitallium screws is preferable to any other metal bar. As Venable and Stuck demonstrated in 1936, dissimilar metals in the body set up sufficient electrolytic activity to cause erosion of bone and loosening of screws.]

For edentulous jaws Ivy and Curtis [291] have used the Roger Anderson apparatus or the Carl Waldron device for external fixation. Two cases are reported in which the latter appliance was used with great success.

Wiring of teeth for fractures of the mandible is uncomfortable and makes for poor oral hygiene. External fixation devices are hard to keep clean and are subject to accidental motion. Pincock [292] has devised a method of drilling a Kirschner wire longitudinally through the body of the mandible and cutting the ends so that the fracture is well supported and yet no external apparatus is visible. The only difficulty is in guiding the wire, and in this article an excellent guide is described, which facilitates the operation.

Berry,[293] who has in the past devised various methods for external fixation of fractures of the jaw, reports a case in which the fracture was fixed with metal staples. With the patient under intravenously induced anesthesia, the fracture was reduced and two metal staples were driven through the skin into the two fragments of bone. No preliminary incision was made and no holes were drilled. The fixation seemed adequate, and the fracture healed with the bone in a normal position.

Skinner and Robinson [294] point out that the fragments of a fractured mandible seldom fail to unite, even in the presence of compound wounds and infections. A bone graft from the ilium, which is held in place by silver wire, and a dental splint will bridge the defect adequately. Even so, the jaw must be splinted for three months to assure proper fixation while healing is taking place.

Adams [295] has abandoned extraoral appliances for the immobilization of facial fractures. Open reduction and fixation by wiring the fractured parts to the neighboring unfractured bones are performed in all cases in which immobilization is indicated. This type of treatment is applicable to every type of fracture involving the facial bones. The procedure is carried out with only a pair of pliers, a small drill and dissection set and a spool of stainless steel wire. Repeated adjustments are unnecessary; the patient is spared much discomfort and inconvenience and is able to resume his activities after recovery from the acute stage of the injury. Open operation is contraindicated in the presence of infection. For fractures of the maxilla, a small incision is made over the infraorbital ridge, and a drill hole is made. A wire is threaded through the opening and looped over the ridge, and both ends are passed together along the anterior wall of the antrum to the region of the second molar teeth. The fractured bone is elevated to its normal position and is wired to the teeth. Several illustrations demonstrate the results of treating fractures of the maxilla and malar bones. [ED. NOTE (J. J. F.).—This is an excellent article, and the reader who is interested in this phase of work should resort to the original.]

Fractures of the Spine and Pelvis.—Conwell [296] uses a Herzmark frame to accomplish reduction of spinal fractures. After emergency treatment for shock has been given, with the

290. Bigelow, H. M.: Vitallium Bone Screws and Appliances for Treatment of Fracture of the Mandible, J. Oral Surg. **1**:131-137 (April) 1943.

291. Ivy, R. H., and Curtis, L.: Recent Experiences with Skeletal Fixation in Fractures of the Mandible, J. Oral Surg. **1**:296-308 (Oct.) 1943.

292. Pincock, D. F.: Horizontal Pin Fixation for Fractures of Mandible Using Pin Guide, Surg., Gynec. & Obst. **77**:493-496 (Nov.) 1943.

293. Berry, H. C.: Simple Skeletal Fixation Method for Quick Repair of a Fracture in War Surgery, J. Am. Dent. A. **30**:1377-1378 (Sept.) 1943.

294. Skinner, H. L., and Robinson, R. L.: Non-Union in Fracture of the Mandible, with Report of a Case, J. Oral Surg. **1**:162-167 (April) 1943.

295. Adams, W. M.: Internal Wiring Fixation of Facial Fractures, Am. J. Orthodontics (Oral Surg. Sect.) **29**:111-130 (Feb.) 1943.

296. Conwell, H. E.: Nonparalytic Compression Fractures of the Spine, J. Omaha Mid-West Clin. Soc. **3**:52-55 (April) 1942.

patient under the influence of opiates or tribromoethanol, hyperextension is obtained by means of a turnbuckle, fifteen to twenty minutes being necessary to obtain correction. It may also be necessary to apply traction to the head and foot. He contends that too severe manipulative procedures or too early application of a tight body cast may cause paralytic ileus. After reduction the patient is allowed to remain on the frame for a few days, after which time the plaster cast is applied. In certain cases an anteroposterior plaster shell may be used. If the economic status is good, the patient remains on the frame from five to six weeks; then a cast is applied and is worn six weeks. A Taylor brace is then worn until roentgenograms show restoration of the fractured vertebrae. He points out that renal stones developed in a number of his patients. [ED. NOTE (J. J. F.).—This author has well emphasized the importance of avoiding early manipulation and immobilization with a cast, so as to avoid paralytic ileus.]

In the Kolar gold field, Dunkerley [297] saw 50 cases of fracture of the vertebrae, with evidence of damage to the spinal cord in only 4 cases. He preferred the Watson-Jones "two table method" of reduction. There was only one cervical dislocation in this series of cases. [ED. NOTE (W. G. S.).—This long article reviews all the details of anatomy, type of injury, and various plans of treatment and in addition gives a thorough account of the recent literature on vertebral fractures.]

Many men working in the Middle East were admitted to an Austrialian general hospital in 1942 with injuries of the cervical part of the spine. Many of these injuries were caused by the men diving from one another's shoulders into shallow water near the beaches. West [298] describes a light cast which he has devised for immobilizing the cervical portion of the spine in hyperextension. It consists of a waistband of plaster, two shoulder straps of plaster and a posterior prolongation which supports the back of the head and extends forward to the forehead.

A concise historical review of experimental and clinical work concerning injuries of the spinal cord is presented by Kennedy, Denker and Osborne.[299] They favor early laminectomy for injuries to the spinal cord. The case histories of patients treated according to this principle are included. Early laminectomy is advocated for the following reasons: (*a*) It is impossible to determine clinically whether an apparently complete transverse lesion of the cord is not really a temporary physiologic interruption of function. Waiting from two to four weeks for "spinal shock" to subside is, according to the authors, a ridiculous procedure, (*b*) Negative results of a roentgenographic examination do not exclude a bony lesion of the spine. (*c*) Prolonged compression of the cord, as evidenced by manometric block, which might have been cured by early surgical treatment, can destroy function of the cord. (*d*) The operation is associated with little risk as soon as general shock has been treated. In the authors' opinion, an experimental study should be undertaken comparing early laminectomy with conservative or traction methods.

Taylor [300] discusses at length dislocation of the pelvis, including in particular dislocation of the symphysis pubis with accompanying sacroiliac subluxation. He discusses the incidence and recommends treatment with a sling or a similar apparatus. He is not impressed with the results of open operation for this condition.

Fractures of the Upper Extremity.—Fractures of the Clavicle: Fracture of the clavicle is an outstanding example of an injury for which no universally applicable method of treatment has been found and for which, therefore, a great many different methods of treatment have been described. Sutherland and Rowe [301] present a brief report of 2 cases in which the patients were treated in recumbency by skeletal traction. [ED. NOTE (R. B. R.).—In the relatively few instances in which traction is necessary, it can usually be obtained effectively and safely by application of the pull to the skin of the arm.] Masland [302] descibes an ambulatory splint which is designed to hoist the shoulder on the injured side by means of a halter which goes about the other side of the neck.

Fractures of the Humerus: Key [303] writes that for widely displaced fractures, fracture-dislocations and severely comminuted fractures of

297. Dunkerley, G. E.: Fractures and Dislocations of the Vertebrae with a Report on Fifty Consecutive Cases, Indian M. Gaz. **78**:202-213 (April) 1943.

298. West, E. F.: Observations on the Treatment of Certain Types of Fractures and Dislocations of the Cervical Part of the Spine, M. J. Australia **1**:557-558 (June 19) 1943.

299. Kennedy, F.; Denker, P. G., and Osborne, R. L.: Early Laminectomy for Spinal Cord Injury Not Due to Subluxation, Am. J. Surg. **60**:13-21 (April) 1943.

300. Taylor, R. G.: Pelvic Dislocations, Brit. J. Surg. **30**:126-132 (Oct.) 1942.

301. Sutherland, R., and Rowe, M. J., Jr.: Clavicle Fracture Treated with Skeletal Traction, Ann. Surg. **116**:950-951 (Dec.) 1942.

302. Masland, H. C.: A Positive Shoulder Lift for Fractured Clavicles, Am. J. Surg. **60**:154-155 (April) 1943.

303. Key, J. A.: Wire Fixation of Fractures of the Proximal Third of the Humerus, Arch. Surg. **46**:678-680 (May) 1943.

the proximal third of the humerus, injuries which are often difficult to treat by manipulation or traction, open reduction is frequently the best method of treatment. He describes briefly the operative technic. If the fragments are stable when reduced, no internal fixation is necessary. A powdered sulfonamide compound is placed in the wound, and after closure a Velpeau bandage is applied. Ten days later the cutaneous sutures are removed, a hanging cast is applied and exercises for the shoulder are started. To this more or less standardized method of treatment, Key contributes the idea of fixation of the fragments at operation by means of two Kirschner wires; these are put through the skin of the lateral and superior aspects of the shoulder and drilled backward and downward, crossing the fracture line. They give a quick and convenient fixation, and no foreign body is left after the wires are pulled out, two to three weeks after operation. [Ed Note (R. B. R.).—This appears to be a useful means of internal fixation for fractures which are difficult to handle by other methods. It should be helpful occasionally for the slipped epiphysis of the humeral head of adolescents.]

Additional reports on the treatment of fractures of the upper end of the humerus without operation or cast are made by Brostrom [304] and Caldwell.[305] Brostrom reports experience with 97 cases, in 61 of which the surgical neck was involved, in 6 the shaft and in the remainder the tuberosities or the anatomic neck. In some cases reduction was carried out. Uniformly, however, an axillary pad was used and the arm fixed to the side of the body by a wide bandage which left the elbow free; the wrist was supported by a sling suspended from the neck. For three days the patients were treated with heat through the bandage, after which light effleurage of the entire extremity and exercises to extend the elbow were carried out daily, with passive circumduction at first and active circumduction later. The dressing around the arm and the chest was discarded in three to four weeks and the sling seven to ten days later. The patients received an average of twenty-three physical therapy treatments. Of eighty-two known end results, twenty-seven were excellent and thirty-two good. Brostrom considers this a superior method of treatment because no elaborate equipment is necessary, no prolonged recumbency is required, the patient is comfortable and stiffness and traumatic arthritis are minimized. [Ed. Note (R. B. R.).—This, of course, is hanging cast treatment without the cast and might be called the hanging arm treatment. In most cases it is probably an excellent method. After fracture of the upper end of the humerus, avoidance of contractures is much more important than anatomic reposition of the fragments.]

R. S. H.,[306] whose full name is not given, has enlivened the year's literature on fractures with an unimportant but amusing and well written case report entitled "The Place of Organized 'Elbow Lifting' in Treatment of the Fractured Humerus." The patient, a British squadron leader, had a crack fracture of the surgical neck of the humerus and complete detachment of the greater tuberosity. His treatment began with active movement under water on the fourth day; the patient "enjoyed it immensely as the difficulties in normally getting a bath at E——, which is a widely dispersed and exquisitely uncomfortable camp, are enormous." Beginning on the ninth day he was forbidden to use his uninjured arm to raise any beverage to his mouth. This involved frequent and purposeful lifting of the elbow on the injured side. Times of treatment corresponded approximately with opening times of the bar. Half pints only were allowed to be used at first. Under the constant encouragement of many friends and under the pleasantly mellowing and possibly mildly anaesthetic effect of what was drunk, the patient succeeded in lifting his elbow to the level of the shoulder by the eleventh day." He was able to return to full ground duty in two weeks.

In a well presented article Stuck [307] describes the management of the various types of fractures involving the humerus. Incomplete fracture of the greater tuberosity, fracture of the anatomic neck and fracture of the surgical neck without displacement are treated with a sling. When traction fails in cases of fracture of the surgical neck with displacement, open reduction and fixation with a screw or wire are done. For fracture-dislocation of the humeral head, open reduction is usually necessary. Resection of the humeral head is not warranted for a fracture-dislocation. The hanging cast method offers advantages over the usual types of treatment for fracture of the shaft. Stiff shoulder is overcome by swinging exercises with this type of treatment. In cases in which the radial nerve

304. Brostrom, F.: Early Mobilization of Fractures of the Upper End of the Humerus, Arch. Surg. **46**:614-615 (May) 1943.

305. Caldwell, G. A.: The Treatment of Fractures of the Upper End of the Humerus, Rocky Mountain M. J. **40**:33 (Jan.) 1943.

306. The Place of Organized "Elbow Lifting" in Treatment of the Fractured Humerus, St. Barth. Hosp. J. **47**:102 (March) 1943.

307. Stuck, W. G.: Anatomical and Mechanical Features of Treatment of Fractures of the Humerus, South. M. J. **36**:543-549 (Aug.) 1943.

is injured and there is no evidence of recovery in the first few weeks, the author assumes that the nerve has been lacerated or compressed and advises exploration. Flexion without manipulation does not reduce supracondylar fractures. It is necessary to exert downward traction and push the distal fragment forward as the elbow is flexed. Close observation of the radial pulse must be made subsequently. For fracture displacement of the internal or external humeral condyle, open operation and replacement with a nail or screw are recommended. Open operation and fixation either with screws or nails are used to treat T fractures of the lower end of the humerus. In cases in which there is severe comminution, operation is not advisable and early motion to prevent stiffness is carried out. [ED. NOTE (J. J. F.).—In cases in which reduction cannot be accomplished by manipulation and in cases of comminuted fracture, traction by means of a screw through the upper end of the ulna has been found satisfactory.]

Smith [308] discusses the disadvantages of several methods of applying traction for fracture of the distal half of the shaft of the humerus with the patient in the recumbent position and presents an adaptation of Russell double pulley traction for treating this type of fracture. No unusual equipment is required, the vertical components are balanced and effective traction is exerted in the longitudinal axis of the arm. [ED. NOTE (R. B. R.).—This appears to be a good method for the unusual fracture for which prolonged traction with the patient in recumbency is needed. Most fractures of this type can be satisfactorily handled by a hanging cast if the patient is ambulatory or by the application of traction to the cast near the elbow if the patient must remain in bed.]

Aitken, Smith and Blackett [309] have studied the end results in 50 cases of supracondylar fracture in childhood. Using a minimum follow-up period of three years, they have attempted to determine the results of malalinement and to develop a more satisfactory method of treatment. They found almost uniformly excellent function, but in 15 cases in which a varus deformity was present poor cosmetic results occurred. The authors concluded that, despite incomplete reduction, supracondylar fracture with radial displacement and external rotation of the distal fragment tends to show excellent functional and cosmetic end results. On the other hand, ulnar displacement plus backward displacement or internal rotation of the distal fragment leads invariably to persistence of a varus deformity. The writers think that development of this deformity following a satisfactory reduction may well be due to the practice of placing the forearm across the chest; unless the fragments are tightly locked with the elbow in acute flexion, the forearm and the distal fragment may rotate inwardly on the humerus. To prevent this complication, they recommend a plaster swathe about the chest; this is fixed to the arm cast and holds the extremity externally rotated. They suggest that this may not be necessary when it is possible to maintain acute flexion of the elbow. They condemn the dictum that accurate reduction is not essential for a good result. [ED. NOTE (R. B. R.).—This explanation of varus deformity after supracondylar fracture of the humerus is plausible and should make one most careful in correcting any medial or rotatory displacement of the distal fragment. In the cast the elbow must be kept acutely flexed, and the cast must be sufficiently tight to prevent movement at the elbow. With preliminary adhesive traction in those cases in which swelling has resulted from a delay in treatment, the right angle position and the cast around the chest will probably not be necessary in a great number of instances.]

de Abreu[310] calls attention to the complex problems of supracondylar fracture of the humerus and emphasizes the fact that a perfect knowledge of the anatomy of the region with application of good conservative orthopedic treatment may limit surgical indications and lead to good anatomic as well as functional results.

Fractures of the Proximal End of the Radius: Burton [311] reviews 50 consecutive cases of fracture of the head of the radius observed in Royal Air Force personnel. He has classified the fractures into three groups, as follows: 1. Impaled fracture, resulting from a fall on the outstretched pronated hand. The author states that the cartilage of the capitellum is usually injured with this type of fracture and that a roentgenogram made two weeks after the injury may show evidence of this. 2. Marginal fracture, resulting from an abduction strain on the elbow with the forearm pronated. A segment of the articular surface of the head is fractured and may not be displaced. An injury of the capitellar cartilage sometimes occurs. 3. Undisplaced fissure

308. Smith, D. W.: Double Pulley Humeral Adaptation of Russel Traction, Surgery **13**:62-66 (Jan.) 1943.

309. Aitken, A. P.; Smith, L., and Blackett, C. W.: Supracondylar Fractures in Children, Am. J. Surg. **59**: 161-171 (Feb.) 1943.

310. de Abreu, M.: Humerus Fractures: Complete Supracondylar Fracture, Rev. brasil. de ortop. e traumatol. **3**:245-260 (July-Aug.) 1942.

311. Burton, A. E.: Fractures of the Head of the Radius, Proc. Roy. Soc. Med. **35**:764-765 (Oct.) 1942.

fracture, resulting from direct injury of the elbow and consisting of a transverse fissure without displacement. The author considers excision of the head advisable for nearly all impaled fractures. Excision was performed for marginal fractures when the segment was displaced or the integrity of the articular plateau disturbed. For marginal fractures without displacement and for fissure fractures, conservative treatment was carried out. The percentage of good results was notably poor only in a group of 9 impaled fractures which were treated without operation, only 2 of these obtaining a good result. The author noted no instability of the superior or the inferior radioulnar joint, cubitus valgus or formation of new bone after operation. [ED. NOTE (R. B. R.).—This classification is interesting; it is to be regretted that the text is not accompanied by illustrations. The absence of complications may possibly be due to a short follow-up period, no definite time being stated.]

Mason and Shutkin [312] contrast favorably treatment of fractures of the head and neck of the radius by immediate active motion with conventional treatment with a cast. They point out that their observations apply only to fractures without displacement or with minimal displacement and that their follow-up period of less than a year is inadequate. The patients treated by early active motion were given a sling, continuous hot wet packs to overcome muscular spasm and active exercise of the elbow twice daily. The authors found that the group treated by early active motion and without a cast had a shorter stay in the hospital, less calcification in the soft tissues and better function of the elbow than the group treated by conventional methods. They think that these advantages may be due to several factors. The fractured fragments are small and uncontrollable; early active motion may permit them to be moved across the fixed articular surface of the humerus to attain the position where maximum function is possible; local heat in the form of hot packs permits early elimination of the reaction of soft tissues and lessens the tendency toward calcification of soft tissues. [ED NOTE (R. B. R.).—The details of therapy for the 7 patients treated "conventionally" are not given; consequently, a comparison with the other method is invalidated to a large extent. It is questionable that hot packs are the best treatment for the acutely injured elbow.]

312. Mason, J. A., and Shutkin, N. M.: Immediate Active Motion Treatment of Fractures of the Head and Neck of the Radius, Surg., Gynec. & Obst. **76**:731-737 (June) 1943.

Fractures of the Carpal Scaphoid Bone: Childress [312a] records a case of fracture of the distal fragment of a bipartite carpal scaphoid bone in which malunion of the distal fragment occurred. He emphasizes the advisability in confusing cases of comparing roentgenograms of the injured bone with those of the scaphoid bone of the uninjured wrist. He also points out that the line of division of a bipartite scaphoid bone runs obliquely from near the outer end of the articular surface of the radius to about the middle of the convexity of the head of the capitate bone.

Fractures of the Hand: In a report of 30 cases of fracture of the metacarpal bones, Cobey, Hansen and Morris [313] present a method of securing traction with a towel clip in the bone with rubber bands fastened to a wire loop. There were no infections, because aseptic surgical technic was used, preliminary incisions were made in the skin and the towel clips, unlike wires, did not permit side to side motion. The authors present evidence to show that excellent positions can be secured and fractures can be perfectly immobilized by this novel method.

Berkman and Miles,[314] on the basis of 20 cases, describe a method of splinting fractures of the metacarpal bones by passing one or two Kirschner wires through the fractured bone into the adjacent sound bone. Fixation of this type is so secure that no cast or external splint is needed. They state that men in the army are able to perform light duty in three or four days after this procedure.

Rosa dos Santos [315] draws attention to the high incidence of fractures of the base of the first metacarpal bone and emphasizes the serious sequelae of improper treatment. He presents a classification of the various anatomopathologic types and discusses the mechanism of the lesions and their respective therapeutic indications. He describes 3 cases in detail.

Fractures of the Lower Extremity.—Fractures of the Femur: Lutz [316] reviews the treatment of fractures of the femur, particularly compound fractures as they occur on the battle-

312a. Childress, H. M.: Fracture of a Bipartite Navicular, J. Bone & Joint Surg. **25**:446-447 (April) 1943.

313. Cobey, M. C.; Hansen, H. C., and Morris, M. H.: Use of Skeletal Traction in the Hand, Army M. Bull., July 1943, no. 68, pp. 135-141.

314. Berkman, E. F., and Miles, G. H.: Internal Fixation of Metacarpal Fractures Exclusive of the Thumb, J. Bone & Joint Surg. **25**:816-821 (Oct.) 1943.

315. Rosa dos Santos, W.: Metacarpus Fractures: Bennett Fracture with Report of Cases, Rev. brasil. de ortop. e traumatol. **4**:1-14 (Jan.-Feb.) 1943.

316. Lutz, A. R.: Fractures of the Shaft of the Femur: A Review of Treatment of Femoral Shaft Fractures, West Virginia M. J. **39**:111-114 (April) 1943.

field. The first principle is the treatment of hemorrhage and shock. Morphine is given and replacement of fluid in the form of blood or plasma started as soon as possible when indicated. Prophylaxis of infection is carried out by local application of sulfonamide compounds and sterile dressings. Débridement is done as soon as possible, preferably before six hours. After twelve hours it is contraindicated. Sulfonamide drugs are given orally and applied locally, and the author presents a routine for cleansing wounds. Complete immobilization is advocated, and the different methods for this as well as for traction and fixation are outlined. The author lists skeletal traction with a Kirschner wire and as much as 35 pounds (15.9 Kg.) as the preferable method. He emphasizes, however, that even under ideal conditions no single method is adequate in all cases. Mention is made of the Haynes apparatus and the Roger Anderson fracture unit.

Joldersma [316a] describes experiences with the use of the Townsend-Gilfillan stainless steel plate in the operative fixation of fractures of the tibia and femur. This report is not a chronicle of a series of cases but rather a development of the theory of application of this type of fixation. The plate, which has been described in other publications, derives its strength from the fact that it is built like an angle iron bridge girder, with slots in the shank for screw holes. The plates can be stacked; it is claimed that two nested plates give five times the support of a single plate. Joldersma states that it is unnecessary to use casts as auxiliary support after the use of the screws and plates described, citing 14 of 15 cases of fracture of the tibia as proof of this contention. The claim of the author that "obliteration of the fracture line occurred in four weeks and solid union was observed in eight weeks" may be disputed by many surgeons who have had contrary experience. The following rules are given to guide the surgeon: (1) Acute clean fractures if seen within five hours are plated immediately; (2) fractures more than six hours old are put in suspension traction for fourteen days, and (3) compound fractures are plated after two or three weeks. The main conclusion of this article is to the effect that return to full duty after fracture of the tibia can be reduced from seven monhs to three and after fracture of the femur from nine months to five.

The well known Thomas walking caliper splint with round or oval ring has not met the requirements of a weight-bearing splint which will transmit pressure evenly to the tuberosity of the ischium. Young [317] has devised an ischium-bearing brace that seems to present several advantages. The half-ring is modeled to fit the ischial tuberosity snugly without pressure on the adductor muscles. The hinge at the ankle is placed directly opposite the ankle joint, so that there is no movement of the brace when the ankle is moved. The brace is carefully described and well illustrated for the guidance of the brace maker.

Schenken and Coleman [318] state that embolism of bone marrow after fracture of a long bone has not been described. They report the case of an 86 year old woman with a fracture of the neck of the femur, which was treated by the insertion of three screws. The patient died four days later. Pathologic examination of the lungs revealed emboli of bone marrow in branches of the pulmonary artery.

Pollock and Brooks [319] describe a device for mobilizing the lower extremity after operation or injury. It consists of a splint to hold the extremity, with joints that can be moved by the patient and a wheel and rail to facilitate the motion. It is especially useful in encouraging motion of the hip and knee in elderly persons with arthritis.

Pridie [320] states that compound fractures of the femur occurring as a result of road accidents in peacetime necessitate only a plain sterile bandage for the wound and splints applied down the side of the body. The patients are usually in the hospital within a few minutes after the accident. Casualties of an air raid who can be transferred rapidly to a hospital need similar first aid treatment. The author saw no Thomas splints used during the Bristol air raids, and the patients reached the hospital in good condition. As he points out, many of the patients had large lacerated wounds of the buttocks, which would have prevented use of Thomas splints. The transportation of war casualties is often over rough ground, so that extensive immobilization is required, preferably with a cast. Since evacuation may take many hours, sulfonamide drugs must be used in the wound whenever possible. In Libya a plaster spica cast with an incorporated Thomas splint to maintain traction on the leg

316a. Joldersma, R. D.: Fallacies of Bone Plating, Am. J. Surg. **60**:50-55 (April) 1943.

317. Young, C. S.: A Half-Ring Splint for Fractures of the Femur and Tibia and for Other Disabilities of the Lower Extremity, Surg., Gynec. & Obst. **77**:518-522 (Nov.) 1943.

318. Schenken, J. R., and Coleman, F. C.: Bone Marrow and Fat Embolism Following Fracture of the Femur, Am. J. Surg. **61**:126-127 (July) 1943.

319. Pollock, G. A., and Brooks, G.: The "Railed" Splint, Brit. M. J. **2**:638 (Nov. 28) 1942.

320. Pridie, K. H.: Compound Fractures of the Femur, M. Press **209**:231-233 (April 14) 1943.

was found to be the most satisfactory of all splints. However, it was learned by tragic experience that such casts should be split along the involved side to prevent constriction and circulatory obstruction. [Ed. Note (W. G. S.).—The plaster of paris spica cast with the incorporated Thomas splint has now become justly popular as "the Tobruk splint."]

Caldwell [321] analyzes the end results in 42 patients with subtrochanteric fracture of the femur. Of 36 patients treated without operation but with Russell traction or a Thomas splint, 2 died and union resulted in all 34 survivors. Two were not able to bear weight before eight months, and in others shortening resulted. On 6 operation was performed with the posterior approach. A cast was made prior to operation and bivalved. The patient was placed face down on the table, and an incision was made along the posterior border of the fascia lata beginning with the greater trochanter and extending downward 8 to 10 inches (20.3 to 25.4 cm.). The biceps femoris muscle was separated from the vastus lateralis muscle; exposure was easy, and reduction was maintained by bone plates. In all cases union was prompt, with good results. [Ed. Note (J. J. F.).—While this may be a rational procedure for the experienced surgeon, it would seem that it should not be performed by the occasional operator.]

In a study of 77 cases of lateral fracture of the femoral neck, Pique and Valls [322] found that all of the fractures consolidated. Skeletal traction was shown to be superior to the Whitman cast, the anatomic and functional results being definitely superior. Skeletal traction diminishes the morbidity and the mortality rate during treatment since it permits easier therapeutic measures. Best results are obtained if skeletal traction is maintained to the end of cure, in order to avoid possible displacement of the fragments.

Williams [323] describes an emergency splint for the fractured femur (and adjustable for the bones of the leg) made up entirely of personal equipment, which can be applied by two untrained men in the absence of skilled assistance. The wounded man is placed in an extended position, with limbs together. One man grasps the heel and foot of the injured limb, extends the limb steadily and maintains the extended position until bandaging is complete. The other man places a rifle along the outer side, with the butt well up to the arm pit, first removing the bolt and insuring that neither rifle nor magazine contains any cartridges; he then extracts a pull-through cord, ties the patient's boot laces together and with a large handkerchief or field dressing puts a figure-of-eight bandage around the rifle, ankle and boot, tying it off on the sole of the boot; then he encircles the upper part of the chest with one belt and the hips with another, passing each one around the rifle first when length permits. Two field dressings are next applied, the pads on the wound as far apart as possible, the short end of the bandage carried to the outer side and the long end brought around under the thigh, around the rifle and then over and around both thighs, being tied off to the short end, with the knot on the rifle. A pair of anklets buckled together are placed around both legs just below the knees, and then the pull-through cord is passed around them and tied to give the anklets a firm grip on the legs.

Fractures of the Tibia and Fibula: Thirty-two cases of fracture of the shaft of the tibia and fibula are presented by Lincoln and Gordimer.[324] In 53 per cent of the cases the fracture was treated with Kirschner wire traction, in 28 per cent with plaster only and in 18 per cent by open reduction. The average age of the patients was 36 years, the average period of disability was five and seven-tenths months and the average stay in the hospital was sixty days. The objectives of treatment were the best possible end result and the shortest period of disability consistent with such a result. The authors were satisfied with their results and feel that the treatment of this rather common fracture has greatly improved within the last ten years. Data of the case histories are incorporated in a table. Medicolegal and compensation claims influenced the period of disability.

Henderson [325] presents a case report in which a 26 year old soldier who suffered a compound fracture of the tibia in a motocycle crash died thirty hours after operation. The clinical course was that of respiratory embarrassment. Autopsy showed the fracture to be in good alinement, without vascular damage; the blood vessels of the brain, lungs and kidneys, however, contained many fat globules. Urinalysis before death revealed many fat globules in the urine, which

321. Caldwell, J. A.: Subtrochanteric Fractures of the Femur: An Operative Approach for Open Fixation, Am. J. Surg. **59**:370-382 (Feb.) 1943.

322. Pique, J. A., and Valls, J. E.: Skeletal Traction or Whitman Method Using Plaster Cast in Lateral Fractures of Femoral Neck, Rev. ortop. y traumatol. **12**:191-198 (Oct.) 1942.

323. Williams, P. L. W.: An Emergency Thigh Splint, J. Roy. Army M. Corps **79**:310-311 (Dec.) 1942.

324. Lincoln, J. R., and Gordimer, H.: Fracture of Shafts of Both Bones of Lower Half of Leg, Arch. Surg. **46**:697-704 (May) 1943.

325. Henderson, R. G.: Fat Embolism After Compound Fracture of Tibia, Lancet **1**:297-298 (March 6) 1943.

proved to be animal fat. This was the only finding which gave a clue to the cause of the fatality.

Griesemer [326] reviews some of the methods that have been used in the management of fractures of the tibia and fibula under his supervision. The simple fracture with little or no displacement requires no reduction and is immobilized by anterior and posterior plaster splints for eight weeks. When weight bearing is allowed during the period of fixation, the nonpadded cast of Bohler is applied. The walking iron is used only for transverse fractures, because the author has seen a disturbance of position when it is used for spiral or oblique fractures. Fractures with displacement are reduced with local or general anesthesia, with the leg flexed to a right angle and placed in a Bohler frame with traction. The fragments are molded into place, checked with roentgenograms and immobilized in a nonpadded cast, which is kept on for eight weeks. Comminuted, spiral or oblique fractures require some form of skeletal traction. A steel pin or a Kirschner wire is placed through either the lower end of the tibia or the os calcis, and traction is instituted, followed by roentgenographic examination within thirty-six hours. If the position is satisfactory, a cast is applied and the wire incorporated in the plaster. Frequently the traction is continued until the cast is thoroughly dry. Overpull of the fragments must be avoided or may lead to delayed union or nonunion. If open reduction is required, this is usually done six or seven days following the injury. The original skeletal traction is maintained during the operation, and the author believes that stainless steel wire, if properly placed, effects satisfactory fixation and avoids the more extensive, time-consuming operation of plating. Sulfanilamide and fixation with plaster are used without fenestrating the cast. Compound fractures should be promptly debrided and reduced in six hours, with closure in certain cases. For those seen after six hours, débridement is not done; simple cleansing is the procedure, followed by the use of sulfanilamide and petrolatum gauze with plaster fixation. For nonunion, the sliding inlay graft of Albee has given the best results. The author and his associates have come to the conclusion that the most important factor in the treatment of these fractures is the skill of the surgeon rather than the particular method of management.

326. Griesemer, W. D.: Management of Fractures of Tibia and Fibula, Pennsylvania M. J. **46**:590-594 (March) 1943.

Shaar, Kreuz and Jones [327] discuss the use of the Stader splint for fractures of the tibia and fibula. A detailed discussion is given, including its application and use and the many errors in application. A group of clinical cases with excellent results is included. The authors recommend the used of the Stader splint for these fractures.

Silvis [328] gives a detailed description of how to make and use a Bohler frame. He prefers this type of frame to the Stader reduction splint, stating that it is simpler. His technic carefully follows that of Bohler.

Ronald [329] presents a short series of fractures of the tibia and fibula to demonstrate the advantages of operative fixation by means of a screw. The operation is performed seven to ten days after injury through a 4 inch (10 cm.) incision. The fracture is reduced and the ends of the bone held in a Hey Grove clamp. A vitallium screw of the correct length is then placed as nearly as possible at right angles to the line of fracture, so that it transfixes an equal thickness of bone in each fragment and engages the cortex of each fragment. Placing of the screw is more difficult in transverse fractures. In order to avoid subcutaneous projection of the head of the screw a V-notch is cut ¼ inch (0.64 cm.) deep. The hole is drilled from the apex of the notch, which is then deepened sufficiently to accommodate the head of the screw. The screw is driven in. The stability of reduction is tested, the periosteum closed, the skin sutured and a padded plaster cast applied. With spiral fractures plaster fixation can usually be discarded in seven to nine weeks and weight bearing in plaster may be safe even earlier. Transverse and comminuted fractures are immobilized in plaster for eleven to twelve weeks. This technic was used for 12 fractures, 9 of which were spiral, 1 transverse and 2 comminuted. Union was sound in all cases, as shown by clinical and roentgen examination. The average time of union was several weeks less than that for tibial fractures treated by other methods. The instability of oblique and spiral fractures makes it necessary to prevent redisplacement either by internal fixation or by continuous traction. The advantages of internal fixation are that perfect apposition

327. Shaar, C. M.; Kreuz, F. P., Jr., and Jones, D. T.: Fractures of Tibia and Fibula: Treatment with Stader Reduction and Fixation Splint, S. Clin. North America **23**:599-630 (April) 1943.

328. Silvis, R. S.: Tibia Fractures: Treatment on Board Ship, U. S. Nav. M. Bull. **41**:331-338 (March) 1943.

329. Ronald, A.: Fixation of Oblique and Spiral Fractures of the Tibia by a Single Vitallium Screw, Proc. Roy. Soc. Med. **35**:763 (Oct.) 1942.

and excellent fixation are secured with a minimum of foreign material and that rapid union is promoted. The patient is ambulatory at an early date, and the period of immobilization in plaster is reduced. The only disadvantage is the danger of sepsis; under normal conditions this complication should not be encountered.

Fractures of the Ankle and Foot: Potvin [330] classifies fractures of the ankle as follows: (1) fractures of the mortise, including low fractures with and without displacement and no diastasis, median fractures with diastasis (Dupuytren) and high fractures (Maisonneuve); (2) fractures of the mortise and the tibial end, including fractures of the posterior and the anterior lip and fractures by tibial crushing. The mechanism of a fracture is in direct relation to secondary deformities discovered clinically and roentgenographically. It may be caused by external rotation, abduction, adduction or a fall.

Lee and Horan [331] discuss the internal fixation of fractures of the ankle. Certain injuries around the ankle do not give uniformly satisfactory results if treated by conservative methods. Consequently, the authors offer certain conditions which require open reduction and internal fixation and present a technic which has given excellent results: 1. Fracture of the lower end of the fibula when the fibular end is displaced outward and backward and the joint mortise is widened or when the fragment is serrated and precludes alinement by manipulation requires open reduction with internal fixation. The fragment is exposed, reduced and fixed with a long vitallium screw through the cortices of the fibula and tibia, and a plaster boot is applied. 2. Trimalleolar fracture in which the posterior tibial fragment includes a quarter or more of the tibial surface requires operative intervention. This fracture disrupts the gliding, weight-bearing surface of the tibia. The fragment is reduced by a Steinmann pin inserted into it posteriorly and a vitallium screw inserted anteriorly. 3. Fracture of the anterior tibial surface is usually comminuted and disrupts the tibial weight-bearing line. It is reduced by driving a Steinmann pin into the anterior fragment and fixed by a vitallium screw. 4. Fracture of the internal malleolus may result in nonunion if fibrous tissue is interposed. The fragment is easily reduced if exposed; it is then fixed to the tibia with chromic catgut. 5. Pott's fracture may be complicated by soft tissue between fragments or dislocation of the posterior tibial tendon. This tendon is exposed, released from between the astragalus and the tibia and restored to its usual position. Other ligaments are repaired. 6. Separation of the tibia and fibula may result in widening of the joint mortise, with resultant pain and disability. Internal fixation with Kirschner wire equipped with thumb nuts for tightening is satisfactory. Traction is used if necessary. 7. Separation of the lower epiphysis of the fibula with backward displacement and interposition of a bone spicule requires open reduction. 8. Recurrent dislocation of the peroneal tendons is accompanied by a jarring snap and pain. The ligaments may be lax, the groove for the tendon too narrow or a supernumerary tendon may exist. Repair is done by anchoring the tendons and reenforcing them. Plaster fixation is used after all of these procedures.

Moritz [332] presents an interesting account of ski injuries. In the three years before May 1942, there were at Sun Valley, Idaho: 257 fractures, 35 dislocations, 762 sprains, 147 contusions, 57 abrasions and 114 lacerations. A ski patrol constantly on duty administered first aid and transported the casualties to the medical department. One hundred and eighty-seven of the 257 fractures (or 72 per cent) involved bones of the lower extremity. Practically all of these were due to torsion strains and rotation of the leg in falling. The most common fracture was a long spiral break in the tibia. Injuries of the foot were relatively infrequent. While there were 270 injuries to the knee, the semilunar cartilages were damaged in only 7 of these. The types of ski binding now used are much tighter than before and do not permit the foot to become disengaged in falls. They make for better control of the skis and greater skill in racing but are obviously to blame for the increased number of injuries of the knee and ankle. It is questionable whether ski troops should use such dangerous bindings.

For isolated fractures of the internal malleolus, Meekison [333] favors open reduction and screw fixation. He states that "since the introduction of vitallium this has been the metal of choice." In air crew personnel this method has favored early return to duty. In a group of 235 fractures of the ankle, 23 were fractures of the internal malleolus and 11 produced diastasis of the tibiofibular joint. The fractures of the internal malleolus were explored through an incision directly over the fracture, the fragment was replaced and a vitallium screw was inserted. The head of the screw was buried under the internal collateral

330. Potvin, P.: Anatomy of Instep: Classification and Mechanism of Fractures, Union méd. du Canada **72**:121-124 (Feb.) 1943.

331. Lee, H. C., and Horan, T. B.: Internal Fixation in Injuries of Ankle, Surg., Gynec. & Obst. **76**:593-599 (May) 1943.

332. Moritz, J. R.: Ski Injuries: A Statistical and Analytic Study, J. A. M. A. **121**:97-99 (Jan. 9) 1943.

333. Meekison, D. M.: Fracture of Internal Malleolus and Diastasis Inferior of Tibio-Fibular Joint, Proc. Roy. Soc. Med. **35**:761-762 (Oct.) 1942.

ligament. When there was fracture of the fibula and diastasis, a vitallium plate was applied to the fibula and one long screw was passed through the plate and fibula and into the tibia. Diastasis alone was treated by passing one screw through the fibula into the tibia. If the original roentgenogram showed no fracture, one view was taken with the foot in inversion and another with the foot in eversion. These demonstrated the abnormal motion in the mortise of the ankle. A padded cast was applied postoperatively for ten to fourteen days; it was then changed for a nonpadded cast with a walking heel of Sorbo rubber. After six to seven weeks a Viscopaste bandage was applied for another week or more. [Ed. Note (W. G. S.).—Often perfect reduction of isolated fractures of the internal malleolus can be obtained by strong traction on the foot to the inner side and application of a cast with the foot inverted. Nevertheless, open reduction and screw fixation may hasten recovery and requires less postoperative fixation with a cast.]

Bierman [334] emphasizes the importance of an additional roentgenographic view to demonstrate chip fracture, which is often associated with severe sprain of the ankle. With the severe sprain, there is complete or nearly complete tearing of the middle or anterior or both ligamentous bands, and with a tearing of the middle band a thin fragment of bone is often avulsed. For demonstration of the chip fracture, in addition to the usual anterior and lateral views, the patient lies prone on the table and a sandbag is so placed that the anterior surface of the ankle rests on it. A cardboard film holder is placed between the ankle and the sandbag so that the lower end of the holder extends about 1 cm. beyond the great toe. The foot is held in plantar flexion; the x-ray tube is tilted toward the head, and the central ray is directed toward the dorsum of the foot and at a right angle to it, so that it will penetrate between the detached small fragments and the shaft. For severe sprains, this technic should be used, and if a chip fracture is demonstrated a period of immobilization of six weeks is required. Subluxation of the ankle may be demonstrated by taking roentgenograms of the ankle in eversion. [Ed. Note (J. J. F.).—This is a valuable article because it emphasizes a technic that is ordinarily not employed and that gives valuable information from the standpoint of diagnosis and treatment.]

Gillette [335] finds the number of poor or only fair end results in certain types of fractures of the ankle great. The tendency to treat them by closed reduction is largely responsible. He recommends open reduction and internal fixation if closed methods have not produced accurate replacement. Inaccurate reduction is responsible for the disabling condition of traumatic arthritis. There are four main types of fractures involving the ankle. The eversion type involves the lower end of the fibula with or without rupture of the deltoid ligament. Osteotomy of the fibula and fixation usually suffice. If malunion has existed for a considerable period, it is necessary usually to excise the fibrous tissue between the tibia and the astragalus. Supramalleolar osteotomy may be necessary. If fresh fractures of the fibula are fixed early, when there is a tendency to displacement, major procedures can be avoided. In certain cases of Pott's fracture, it may be necessary to fix the fibula and in addition the internal malleolus if displacement persists. For malunion supramalleolar osteotomy may be necessary, and arthrodesis may be indicated for traumatic arthritis. For the third type, which is the Cotton fracture, open reduction of the posterior malleolus should be done. It may be necessary also to fix internally one or both of the other malleoli. With the fourth type, anterior dislocation with fracture of the anterior margin of the tibia, a nail should be inserted through an anterior incision. If normal function cannot be obtained, fixation of the tibioastragalar joint should be done. When a fusion is done, any malalinement should be corrected by osteotomy before the joint is fixed. [Ed. Note (J. J. F.).—The majority of fractures of the ankle respond favorably to conservative treatment. Open reduction should be reserved for the fractures with which this method fails to effect reduction.]

Alldredge [336] presents a three year study of 56 cases of injury to the ankle which required hospitalization. He points out the mechanism which causes certain types of fractures. He believes that the ligamentous injury is as important in some cases as the fracture itself. In 29 of the 56 cases the fracture of the ankle was an external rotation fracture, in 21 it was an abduction fracture and in 6 it was an adduction fracture. In 29 of the 56 cases, closed reduction was the treatment employed and in 27 open reduction and metal fixation of one type or another were used. It is apparent that absolute anatomic approximation is necessary and should be maintained throughout the course of treatment until bony union is complete. [Ed. Note (J. J. F.).—If only the patients with serious fractures were hospitalized, the incidence of open reduction might not be too high.]

334. Bierman, M. I.: Avulsion Fracture of Fibula, U. S. Nav. M. Bull. **41**:647-652 (May) 1943.

335. Gillette, E. P.: Fractures About the Ankle, Indust. Med. **12**:160 (March) 1943.

336. Alldredge, R. H.: Fractures About the Ankle Joint, New Orleans M. & S. J. **95**:414-423 (March) 1943.

Tobin [337] tags another fracture. "Fracture of the posterior articular margin or 'posterior lip' of the tibia" he designates as a paratrooper's fracture. There is little or no displacement of the fragment, probably because of the support of the tight boot. The treatment consists of immobilization of the joint for four weeks in a skin-tight plaster cast with a walking iron. Full return to duty is expected in three or more months.

Shaar and Kreuz [338] discuss the use of the Stader splint for fractures of the os calcis. In their opinion the Bohler method is too complicated for the ordinary surgeon, and they feel that the Stader splint is simpler and gives better control of the fragments and may shorten the period of convalescence. There is a rather complete discussion of the anatomy, diagnosis, roentgen findings and prognosis of these fractures. [Ed. Note (D. H. O.).—It is interesting to note that these authors feel that the Stader splint is simpler than the Bohler, while others consider the opposite to be true. Each surgeon uses the method with which he is most familiar.]

Rogers [339] discusses at some length fracture of the os calcis produced by a force directed from below, such as the buckling of the deck of a ship. He gives a comprehensive review of the anatomy and discusses the proper roentgenograms to expose the fracture. He recommends the use of the Bohler method with traction on a frame followed by application of a cast. He expresses his preference for this type of fixation over external skeletal fixation with a Stader or similar splint.

Blair [340] describes a new operation for fractures of the astragalus and reports 2 cases. In 1 case there was a fracture-dislocation of the body of the astragalus, and in the other a comminuted neck and head remained in normal position. Through an anterolateral incision, a sliding bone graft was embedded from the tibia to the neck of the astragalus. The results in both cases were good. The author believes that with this operation weight bearing occurs on a normal, undisturbed joint and that there is less tendency to subsequent deformity. He is convinced that this procedure is better than astragalectomy or any other procedure of arthrodesis about the ankle.

Fractures of the os calcis which involve the astragalocalcaneal joint often cause late pain and severe disability. The usual treatment for this complication is subastragalar arthrodesis. The standard types of operation are so formidable and require such painstaking care that they do not always succeed. Gallie [341] describes a simple operation in which through a posterior incision the subastragalar joint is exposed and is fused by wedging a square tibial graft into a square hole cut across the joint. Of 50 operations which the author has performed in the past six years, all but 7 resulted in solid bony union. This is a simple, rapid method for obtaining astragalocalcaneal fusion.

Creer [342] maintains that in many cases of old fracture of the os calcis the midtarsal joint is undamaged and that arthrodesis between the astragalus and the os calcis is sufficient to relieve the pain. He describes a method whereby the joint is fused by the insertion of a small graft. [Ed. Note (W. G. S.).—I doubt if it is possible to tell from the roentgenograms whether the midtarsal joint is undamaged or not. It is a common experience to find on exploration that all the articular surfaces of the calcaneus are crushed and distorted, whether this is demonstrated in the roentgenogram or not.]

Fractures of the os calcis which cause crushing of the articular surfaces of the astragalus or the os calcis result in painful arthritis no matter how well the gross displacement is corrected. According to Watson-Jones, the posterior portion of the astragalocalcaneal joint is involved in 45 per cent of all fractures of the os calcis. Armstrong [343] describes an operation which he has devised and which produces a mechanically stable arthrodesis allowing essential early weight bearing. Through a lateral incision the posterior subastragalar joint is exposed and denuded of cartilage. Through an anterior incision over the neck of the astragalus, holes are drilled through the neck and the posterior subastragalar joint and into the calcaneus. A tibial graft 4½ inches (11 cm.) long is driven into the hole and into the calcaneus. After two weeks the patient is able to bear weight in a walking cast, and solid fusion is obtained in nine weeks. [Ed. Note (W. G. S.).—The author includes pictures showing excellent fusion of the subastragalar joint in nine weeks. However, this is a far from simple operation and can be accomplished

337. Tobin, W. J.: Paratrooper Fracture, Arch. Surg. **46**:780-783 (May) 1943.

338. Shaar, C. M., and Kreuz, F. P., Jr.: Treatment of Fractures of Os Calcis: Presentation of New Method, S. Clin. North America **23**:291-308 (Feb.) 1943.

339. Rogers, W. L.: Os Calcis Fractures in Naval Warfare, U. S. Nav. M. Bull. **41**:324-330 (March) 1943.

340. Blair, H. C.: Comminuted Fractures and Fracture Dislocations of the Body of the Astragalus, Am. J. Surg. **59**:37-43 (Jan.) 1943.

341. Gallie, W. E.: Subastragalar Arthrodesis in Fractures of the Os Calcis, J. Bone & Joint Surg. **25**: 731-736 (Oct.) 1943.

342. Creer, W. S.: Modified Subtaloid Arthrodesis, Proc. Roy. Soc. Med. **36**:333-334 (May) 1943.

343. Armstrong, J. R.: Posterior Subastragaloid Arthrodesis in Fractured Os Calcis, Lancet **2**:506-508 (Oct. 23) 1943.

only with careful roentgenograms taken at each stage of the procedure.]

Metz, Householder and DePree [344] recommend large pressure tongs 3 feet (90 cm.) long with felt-padded blades for the compression of fractures of the os calcis or of the upper end of the tibia. [ED. NOTE (W. G. S.).—This appears to be an improvement over Bohler's clamps or the machinist clamps or the C clamps, which have been commonly used. The tongs are probably easier to control, and the amount of force can be more directly determined than with any of the screw type clamps.]

According to Hauser,[345] fractures of the os calcis have occurred frequently in the present war; they cause a great deal of disability and do not respond well to treatment. Preliminary treatment is directed toward shock and lacerations and is followed by reduction and fixation and establishment of normal function of the foot. A local or general anesthetic is used, with the knee in flexion and the foot in plantar flexion. A Bohler compress may be used and the os calcis reduced manually. Plaster fixation is then utilized until union occurs. Statistics indicate that the disability may vary from 10 to 80 per cent for the injured limb. The author believes that the disability usually results from pain in the heel and that this pain is associated with spasm of the peroneal muscle and valgus deformity of the heel as well as loss of the longitudinal arch; most surgeons, however, consider the pain to be a result of a fracture into the joint, with arthritis and muscular spasm as a sequence. Consequently, the author believes that if the heel is placed in varus and the anterior part of the foot is in pronation normal function without pain will result. Triple arthrodesis, therefore, will seldom be necessary.

Rosa Ribeiro [346] draws attention to the low incidence of fracture of the posterior superior tuberosity of the os calcis, describing the first case to be reported in his country. Studies on the cadaver are described, explaining the mechanism of the fracture. After a study of symptoms, the author discusses the treatment, which consists of early open intervention, osteosynthesis with absorbable material and immobilization in plaster with the foot in equinus. The result was excellent, without postoperative complication of any kind. These fractures lead to forced extension of the achilles tendon and the triceps muscle, with resulting contracture of the musculature.

For multiple fractures of the metatarsal shafts, Marrin [347] demonstrates a method of inserting wires longitudinally through the medulla of the bones. This provides excellent immobilization with the bones in perfect position during the time of healing of the fractures.

War Wounds and Compound Fractures.—Toffelmier [348] reports that in the South Pacific it was found that for transportation of a wounded person a plaster cast was the most successful method of immobilizing a compound fracture. Compound fractures of the femur were treated with a plaster of paris spica with a pin near the knee. Compound fractures of the tibia were supported by means of a full length cast with a pin through the heel. Compound fractures of the humerus were treated with a hanging cast. Surprisingly, most of the men reached hospitals on the mainland with little angulation or deformity.

Of the wounded men on the Eastern Front cared for by Hundemer,[349] 56.37 per cent had injuries of the limbs, and of these 14.91 per cent had wounds of the joints. Fifty-nine per cent of these injuries were in the knee, and about 90 per cent of all injuries of the joints included moderate to severe damage to bone. Emergency treatment for through and through injuries of the joints consisted of sterile dressing, aspiration and immobilization. Open injuries of the joint were transformed into closed ones if seen within sixty hours. Excision, suturing of the capsule and rubber drainage were used. Local chemotherapy did not seem to influence the course of healing. Primary resection of the joint was rarely used, but partial resection (femoral condyle, patella, etc.) was employed. Comminuted fractures into the joint with extensive damage of vessels and nerves call for primary amputation. Foreign bodies should be removed within forty-eight hours. After that they are treated expectantly. Immobilization in plaster of paris should be early and adequate. A spica for the hip is necessary for injuries of the knee joint.

344. Metz, A. R.; Householder, R., and DePree, J. F.: Impaction of Fractures by Large Pressure Tongs, Am. J. Surg. **59**:447-449 (Feb.) 1943.

345. Hauser, E. D. W.: Fractures of the Calcaneus: Treatment of Altered Statics, Physiotherapy Rev. **23**: 51-54 (March) 1943.

346. Rosa Ribeiro, E.: Calcaneum Fractures of Posterosuperior Tuberosity: Experimental Study, Rev. méd. munic. **4**:165-182 (Aug.) 1942.

347. Marrin, M. M.: Multiple Metatarsal Fractures: A Method of Fixation, Mil. Surgeon **93**:81-83 (July) 1943.

348. Toffelmier, D. D.: Experiences with Compound Fractures from the Pacific Combat Area with Presentation of New Appliances for the Care of the War Injured, Bull. Am. Coll. Surgeons **28**:132-133 (June) 1943.

349. Hundemer, W.: Military Experience with Joint Wounds, Bull. War Med. **3**:268-270 (Jan.) 1943.

Perkins [350] presents the treatment of osteomyelitis due to a penetrating wound as follows: In cases of persistent acute osteomyelitis there is little need for surgical treatment because the wound is already opened wide. For severe infections, amputation is the advisable surgical treatment. In cases of a resultant sinus the wound should be explored once for the removal of foreign bodies or dead fragments of bone, which produce continued drainage. The time to do this is after all evidence of inflammation in the adjacent soft tissues has subsided. Recurrent acute osteomyelitis denoted by sudden fever, pain and malaise with old healed osteomyelitis is best treated with hot wet dressings and rest until the abscess has drained itself completely. In cases of sinus with flares diffuse infection in the bone is constantly present, and it can seldom be cured by surgical drainage. For old infections in the lower extremity, amputation may be the preferable treatment. [ED. NOTE (W. G. S.).—This article follows traditional ideas of the prepenicillin era. While not enough proof yet exists, it is possible that penicillin may produce permanent cures in some of the cases of old osteomyelitis secondary to wounds.]

Alexander [351] reviews certain characteristics of burns and compound fractures. Both are open wounds and potentially infected; both are produced by external agents and accompanied by severe shock. With burns, toxemia appears in a few days and requires intensive treatment. The massive compression dressing for burns of the extremities and immobilization with a plaster cast help decrease pain and shock. [ED. NOTE (W. G. S.).—Burns and compound fractures coexist in the same patient often as the result of military or naval accidents. As the author points out, there is a close parallelism in their immediate care.]

Brandt [352] studied the healing of wounds by controlled observation of symmetrically involved extremities. In frostbite, which occurred in the Russian campaign, the wound that was treated with the open method, by cutting a window in the cast, was dry and crusted, and production of pus was less. When the crust was removed granulations were present, and removal interfered with healing. Stumps of bone or tendons were not so quickly covered with granulations as with the closed method. Contraction of the scar was greater when the open method of treatment was used. The author concluded that the open method is indicated when there is much exudation from the surface of the wound and appears to work well for Pseudomonas pyocyanea infections. The closed treatment is used when exposed tendons must be protected from drying up or when spaces must be filled with granulations. The closed method is unsuitable in the presence of profuse suppuration or suspected progressive inflammation.

Compere [353] reports that he treats compound fractures seen within eight hours of the time of the accident, regardless of the degree of contamination, by cleansing, débridement and closure without drainage. The fractures are reduced, with or without pin fixation, and immobilized in a plaster cast. In only a few instances has it been necessary to remove sutures because of sepsis. Compound fractures are turned into simple ones by primary sutures, and the incidence of infection of soft tissue and osteomyelitis is reduced. Healing is rapid, and the scar is linear and nonadherent. If the fracture is seen after infection has developed or too long a time has elapsed to permit primary closure, the wound is explored, with the patient under general anesthesia; necrotic tissue, sequestrums and foreign bodies are removed; the wound is packed with sulfanilamide impregnated in petrolatum gauze, and the extremity is immobilized with plaster. Sulfathiazole is administered orally. In outlining the management of war injuries, the author recommends primary closure, without tension, after careful cleansing, débridement and packing of the wound with sulfanilamide if seen within six to eight hours. It may be necessary to make parallel cutaneous incisions to reduce the tension of the wound. If the patient is seen after eight hours or if the wound is dirty, it is packed open with sulfanilamide and petrolatum gauze. Roger Anderson pins or metal plates are recommended when skeletal fixation is indicated.

Rogers [354] discusses various kinds of infections of wounds, such as gas gangrene and allied types. Since fatal gas gangrene can develop so rapidly, diagnosis must be made without waiting for a cultural study. Fine crepitus about the wound, bubbles in the secretion of the wound, roentgenographic shadows of gas and the characteristic odor should place the surgeon on the extreme

350. Perkins, G.: Surgical Treatment of Osteomyelitis Due to a Penetrating Wound, Brit. M. J. **1**:441-442 (April 10) 1943.

351. Alexander, H. H.: Burns and Compound Fractures: A Review of Their Closed Treatment, Indust. Med. **12**:434-436 (July) 1943.

352. Brandt, G.: Open Treatment or Closed Plaster Treatment of Wounds, Bull. War Med. **3**:305-306 (Feb.) 1943.

353. Compere, E. L.: The Treatment of Compound Fractures in the War Injured, S. Clin. North America **23**:205-210 (Feb.) 1943.

354. Rogers, W. A.: Clostridia Producing Gas Gangrene, New England J. Med. **229**:211 (July 29) 1943.

alert. Other factors aside, the severity of the infection is dependent on the tissues involved: those infections that are confined to cellular connective tissue are mild, while those established in devitalized muscle tissue are apt to be grave. Compound wounds should be thoroughly debrided as soon as possible, sulfonamide drugs should be used locally in the wound and internally and polyvalent antitoxin should be administered. If gas gangrene is suspected, the patient should receive sulfathiazole intravenously, large doses of polyvalent antitoxin should be repeated, wounds should be widely opened and when there is extensive muscular involvement amputation at a high level should be performed as a life-saving measure. Wounds should be treated with a creamy suspension of zinc peroxide. The clinical manifestations of tetanus are due to the toxin produced by Clostridium tetani. The toxin is absorbed by the lymphatics, through which it reaches the blood stream, and by the latter is conveyed to the central nervous system. This route of progress is more likely than the former supposition, that the toxin travels up the motor nerve trunks. Active immunization with tetanus toxoid is likely to cause a marked decrease in the incidence of the disease. The author closes with a description of infections due to the anaerobic streptococci. [ED. NOTE (W. G. S.).—The whole article deserves praise as an up-to-date story of present knowledge of severe infections in wounds.]

In a British manual [355] it is stated that the diagnosis of gas gangrene is often overlooked in its early stages, with disastrous results. An important early symptom is a feeling of weight in the affected limb or stump. After two to eight hours there is much local pain, soon followed by edema, accompanied by a profuse yellowish or brownish yellow serous discharge from the wound. The distinctive odor and discoloration of the skin appear later. Early recognition permits intensive immediate treatment.

Orr [356] restates his cardinal principles of treatment of compound fractures: (1) immediate restoration and maintenance of anatomic relationship; (2) drainage of the open wound in all contaminated or infected areas; (3) protection of the surfaces of the wound by petrolatum dressings; (4) immobilization with the bone in correct position.

Aitken [357] states that with a compound fracture the exposed end of the bone should not be reduced at the scene of the accident but sterile dressings should be placed over it. An adequate neurologic and medical examination should be done before any therapy is carried out. All departments in the hospital, roentgenologic, resident and surgical staff, should be willing to give a patient with this type of injury preference over one with any other type requiring conservative surgical treatment. Therapy for shock, if necessary, adequate preoperative roentgen examination and 1,500 units of antitetanus serum should be given. After surgical débridement, internal fixation is used rather than fixation with a pin or traction on the skin. If there is any question regarding the degree of contamination, the wound is left open, and no wound is closed around a drain. The fracture should then be immobilized in a circular plaster of paris cast. The author urges against cutting out windows in the cast when the wound is packed with petrolatum gauze, because of the possibility of bowing at the site of fracture.

Anderson [358] claims that compound fractures can be easily managed after being immobilized with his type of apparatus. He believes that gas bacillus infection can be treated with roentgen rays more satisfactorily when the fracture is immobilized by this method and that it provides better access for sequestrectomy, skin grafting and removal of foreign bodies. Ambulation with muscular contraction causes increased circulation of blood and lymph. [ED. NOTE (J. J. F.).—In general, multiple pins protruding through the skin are more hazardous than other methods.]

Caldwell [359] reviews the treatment of compound fractures. A compound fracture should be covered with sterile gauze and a splint applied before the patient is transported. Shock should be combated with whole blood or plasma, and a careful survey of other injuries should be made before local treatment is given. When the fracture has become compound from within, the cutaneous margins are excised, sterile dressings applied and the fracture reduced and immobilized in the best obtainable position. When there is evidence of gross contamination of the fragments, exploration and complete débridement are done. The objection to a foreign body buried in contaminated tissue has been overcome to some

355. Clinical Picture of Cl. Oedematiens Gas Gangrene, Bull. War Med. **4**:69 (Oct.) 1943.

356. Orr, H. W.: The Physiologic Factors Involved in Protecting Patient Against Infection in Healing of Fractures in Compound Wounds, Tr. & Stud., Coll. Physicians, Philadelphia **10**:187-193 (Feb.) 1943.

357. Aitken, G. T.: Early Treatment of Compound Fractures, J. Michigan M. Soc. **42**:353-365 (May) 1943.

358. Anderson, R.: Castless Ambulatory Method of Treating Fractures, J. Internat. Coll. Surgeons **5**:458-462 (Nov.-Dec.) 1942.

359. Caldwell, J. A.: Management of Compound Fractures, J. A. M. A. **124**:412-413 (Feb. 12) 1944.

extent by use of sulfonamide drugs. The author has not been convinced that local application of sulfonamide compounds is of any value. Closure should be done loosely and never by layers. Relaxing incisions are used when tension is increased. All patients receive combined tetanus and Bacillus perfringens antitoxin and sulfadiazine by mouth. If streptococci predominate in the wound, sulfanilamide is used. [ED. NOTE (J. J. F.).—Local application of one of the sulfonamide drugs in addition to oral administration seems to be indicated at the present time.]

Davis and Fortune [360] describe the management of compound fractures in considerable detail. Attention should be paid to hemoconcentration, blood count and blood pressure on the patient's arrival at the hospital. The authors emphasize the importance of careful cleansing of the wound with soap and water and saline solution and of adequate débridement. Vitallium plates and screws are used for fixation, and sulfanilamide is placed in the wound. The wound is closed with clips, silk or chromic catgut sutures. In some cases it is necessary to undermine flaps of skin or use a split or full thickness graft in order to close the wound. A compression dressing is used and not disturbed for ten days. Prophylactic gas gangrene and tetanus antiserum are given. The authors report a series of 50 compound fractures. Forty-three healed by primary intention. There were no cases of nonunion, gas gangrene or amputation due to infection. Five of the 7 patients whose wounds broke down are now working, and none of them had serious results. A revision of the method of treatment of compound fractures based on advances in other fields gives fewer amputations, a reduction in sepsis and a decrease in the number of delayed unions and nonunions. The use of sulfonamide compounds has added significantly to the safety of primary closure and to the effectiveness of the open method.

Observation of compound fractures infected with Staph. pyogenes and treated with sulfapyridine and sulfathiazole in addition to standard antiseptic and surgical measures was made by Heggie, Kendall and Heggie.[361] They conclude that sulfathiazole is more efficacious than sulfapyridine in the treatment of compound fractures that have become infected with Staph. pyogenes. The necessity for chemotherapy before and after operation is stressed, as is also the combination of local and oral administration. For local application of a sulfonamide compound does not give adequate bacteriostatic concentration, because of cellular débris, tissues with low water content and resultant low solubility and concentration of the drug. No stapyhylococci which were resistant to sulfonamide drugs were encountered in this series of cases.

Because a mixture consisting of carbamide (urea) 85 per cent, sulfanilamide 13 per cent and sulfathiazole 2 per cent is relatively harmless to normal tissue, hastens healing, eliminates odor from infected wounds, is bactericidal and dissolves dead tissue, Ilfeld [362] favors its use in traumatic wounds. If carbamide is used, the author believes that primary closure of compound wounds may be done many hours after the injury, even though six hours is usually considered the dividing line. The method of treatment consists of scrubbing with soap and water, irrigation, first with isotonic solution of sodium chloride and then with 500 cc. of saturated solution of a mixture of carbamide and sulfanilamide in sterile water, débridement and a second irrigation with saline solution and the carbamide-sulfanilamide mixture. The injury is repaired, and carbamide-sulfanilamide powder is sprinkled in all parts of the wound, which is then closed with primary sutures. In the cases presented, excellent results were obtained. The author states that this mixture, as well as any of the sulfonamide drugs, delays healing and retards epithelization somewhat. Urea accelerates the formation of granulation tissue; consequently at the stage of epithelization the necessity for the use of the carbamide-sulfanilamide mixture has passed. Because of the action of urea, the author feels that the urea-sulfanilamide mixture is superior to a sulfonamide compound alone in the treatment of traumatic wounds.

The results of treating 245 compound fractures of the tibia and fibula are given by Griswold.[363] The surgical principles which he emphasizes are: (1) removing or rendering innocuous the bacteria in the wound without causing additional injury; (2) removing foreign bodies and dead tissue which provide food and protection for the bacteria, and (3) providing rest and protection from tension, trauma and reinfection, so that reparative processes may not be hindered. These objects are accomplished by careful preliminary treatment of the wounds, irrigation and closure

360. Davis, A. G., and Fortune, C. W.: Compound Fractures, J. Bone & Joint Surg. **25**:97-120 (Jan.) 1943.

361. Heggie, J. F.; Kendall, A. W., and Heggie, R. M.: Infected Wounds Involving Bone Treated with Sulphapyridine and Sulphathiazole, Brit. M. J. **2**:655-658 (Dec. 5) 1942.

362. Ilfeld, F. W.: Carbamide Sulfonamide Mixtures: Use in Treatment of Compound Fractures and Traumatic Wounds, Surg., Gynec. & Obst. **76**:427-437 (April) 1943.

363. Griswold, R. A.: Treatment of the Wound in Compound Fractures, J. Indiana M. A. **36**:55-59 (Feb.) 1943.

without tension or petrolatum packing if closure is not used. Sulfonamide compounds complement the surgical treatment. The author emphasizes that compound wounds should be treated as carefully as any elective surgical condition.

Koch[364] emphasizes the contributions of Thomas, Orr, Reid and Blair to the treatment of wounds and compound injuries. Since he believes that wounds of the parietes and the extremities are treated by the same principles as are all other wounds, he offers eight primary considerations. The first is the arrest of hemorrhage and the treatment of shock. Elevation if possible and application of a sterile pressure dressing in the correct place are the important points mentioned by him. Next are the prevention of additional contamination and trauma, the use of masks, sterile instruments and dressings, the avoidance of strong antiseptics and the avoidance of probing the open wound—all tend to prevent external infection. The diagnosis of the extent of the injury is then made with a search for the presence of multiple injuries. It is important to determine the entrance and exit of metal fragments and also to consider in turn the blood vessels, bones, nerves and tendons. The pulse rate, the roentgenogram and the motor and sensory status of the extremity will usually indicate the diagnosis. The contaminated wound is then converted into a clean wound by first washing around the injured area with plain soap and water and then irrigating with copious amounts of sterile saline solution. The wound itself is then cleansed in the same way. The author has had excellent results when he has used this simple method for all open wounds. The foreign material and the devitalized tissue are then excised, the latter being recognized by its color, its failure to bleed and the amount of contusion. As much viable skin and fragmented bone as possible should be saved. The injured structures are then repaired, and the method of closure will depend on the character of the first aid treatment and the time that has elapsed following the injury, as well as the character and extent of the wound. Specific mention is made of injuries with loss of covering tissue, injuries of blood vessels, injuries of bones and joints and injuries of nerves and tendons. For the loss of covering tissues, early application of skin grafts gives the best chance for a satisfactory recovery. The details involved have been stressed by Blair, Brown and Byars, by Davis and by others. Koch emphasizes that closure of the open wound and healing in the minimum time are the objectives. When blood vessels are injured and a foreign body is involved, the author believes that it is wise to expose the area by an adequate incision above and below the foreign body before attempting its removal. With injury of bones and joints, adequate cleansing is followed by reduction and immobilization. The author points out that the exact type of metal or retaining device employed for internal fixation is secondary in importance to the freedom from infection and the healing by primary union. Koch mentions that in order to secure reduction and immobilization of a comminuted or oblique fracture with the aid of pins and distraction apparatus one must have both considerable equipment and adequate training in its use. When nerves and tendons are injured, the tendons should be repaired first because they lie more deeply and because there should be a minimum of manipulation after the delicate nerves are repaired. Best results are secured if the wound heals by primary union and if postoperative relaxation of the injured structures is maintained for from three to four weeks. Adequate immobilization in a position of minimum tension plus moderate uniform compression over the area of the wound is important in the treatment of fractured tendons, nerves and soft tissues as well as bones. The author believes that the essential factors in the success of Orr and Trueta's method are continued and uninterrupted rest with moderate pressure and freedom from repeated bacterial contamination. The last important principle is clean surgical care, which involves a masked mouth and nose, clean hands, clean instruments and "forks, not fingers." Several illustrations of injuries which have been treated by this method are included in the article, and the excellent results are evident.

The care of wounds under emergency conditions is also discussed by Koch,[365] and a description and diagram of an emergency unit are presented. The author mentions chemotherapy and its use for infected wounds. The occurrence of unusual infections such as gas gangrene, chronic undermining ulcers and bacterially synergistic gangrene is discussed and their treatment described. The author makes a slight commentary on burns, repeating that they are large open wounds which require the same principles of treatment that have been stressed for the general treatment of wounds.

Fatigue Fractures, March Fractures and Stress Fractures.—With the vast expansion of armies everywhere, the phenomena of fatigue and the resulting effects on the skeletal system are

364. Koch, S. L.: Injuries of the Parietes and Extremities, Surg., Gynec. & Obst. **76**:1-22 (Jan.) 1943.

365. Koch, S. L.: Injuries of the Parietes and Extremities: Care of Wounds Under Emergency Conditions, Surg., Gynec. & Obst. **76**:189-196 (Feb.) 1943.

brought to the forefront. Peaceful people rarely observe these manifestations, which in the past have become known principally from the literature of the goose-stepping Fatherland.

Hartley [366] discusses fatigue fractures in general terms. Since march fracture was first described in 1855 there have been few reports of fatigue fractures in bones other than the upper third of the tibia, especially in England and America—the two greatest nonmilitary countries. On the other hand, one report showed that in Germany in 1936 there were 590 fatigue fractures, with 70 in the tibia, 13 in the femur, 12 in the fibula, 4 in the os calcis and 3 in the pelvis. Now, with England and America training huge armies, these "stress fractures" are becoming increasingly common. Stress, insufficiency or fatigue fractures occur in apparently normal bone and cause pain on weight bearing. The crack in the bone may be invisible in the roentgenogram but is detected by the formation of subperiosteal callus. Recognition of this condition in the bones of the lower extremity is essential when one is considering vague accumulations of bone that may be confused with formation of tumor, osteitis or osteomyelitis.

Blumenfeld [367] reports a case of spontaneous fracture in the lower third of the tibial shaft in a 23 year old soldier. The patient had been in the army nine months and had been a cook but had taken no part in the drills, athletics or hiking. The fracture line was never complete but more nearly resembled a fissure fracture. Symptoms subsided rapidly when weight bearing was discontinued.

Bush [368] reports a large series of march fractures. March foot is a progressive lesion if not treated early. The patient has a history of acute pain in the anterior portion of the foot while marching a long distance; dorsal swelling and ecchymosis appear over the midmetatarsal region; there is a palpable mass over the involved bone, and sharply localized tenderness is present. In some cases these signs are present without roentgenographic evidence of fracture; in others there is evidence of subperiosteal callus, and finally in some a fracture line can be clearly demonstrated. Predisposing causes are an abnormally elongated second metatarsal shaft, short shoes and extra stress. Treatment by strapping is successful if there is no frank fracture; otherwise, a cast for three weeks is advisable. Of 100 march fractures seen, the third metatarsal bone was involved in 72 and the second metatarsal bone in 25.

Flavell [369] reports 15 cases of march fracture among 4,000 members of the Royal Air Force seen in three months at his clinic. A short or an abducted first metatarsal shaft was the common cause of the undue strain thrown on the second and the third metatarsal shaft. In no case was there preexisting metatarsalgia. There was no persistent pain after healing of the fractures. [Ed. Note (W. G. S.).—Once again the point is made that march fracture is increasingly common in the personnel of the Allied Armies, which are now extremely populous.]

Ingersoll [370] states that march fracture and other fatigue fractures seem to result from fatigue of the muscles, tendons and ligaments. However, "ice skater's fracture" of the lower third of the fibula suggests fatigue of bone just as strain causes the cracks which appear in repeatedly stressed metal. Since bone is a living tissue the usual reparative reactions take place simultaneously, and subperiosteal new bone is formed at the site of the fatigue fracture. Three of these fractures occurred in boys who had received ice skates for Christmas and who were skating for the first time. The author believes that there is much strain on the foot in eversion in skating and that this becomes more marked with fatigue. Strain on the fibula is produced by a slight rotation of the astragalus, and the fibula cracks at its weakest point, 2 to 3 inches (5.1 to 7.6 cm.) above its distal point. [Ed. Note (W. G. S.).—This is an interesting type of fracture and is brought up in current reports on various types of fatigue fractures in the Army.]

Barns [371] reports on 20 march fractures which were seen in a Royal Air Force training station in a few months. All the patients were men in the best physical condition. Pain and limp were the chief symptoms. The author points out that the first roentgenographic evidence of damage of the metatarsal shaft is apparent on the dorsomedial aspect of the bone.

Berkman [372] studied 15 cases of march fracture. In 14 cases the distal third of the second and

366. Hartley, J. B.: "Stress" or "Fatigue" Fractures of Bone, Brit. J. Radiol. **16**:255-262 (Sept.) 1943.

367. Blumenfeld, E.: March Fracture of the Tibia, J. Bone & Joint Surg. **25**:921-924 (Oct.) 1943.

368. Bush, L. F.: March Foot: Its Early Diagnosis and Treatment, Army M. Bull., July 1943, no. 68, pp. 126-134.

369. Flavell, G.: March Fracture, Lancet **2**:66-69 (July 17) 1943.

370. Ingersoll, C. F.: Ice Skater's Fracture: Form of Fatigue Fracture, Am. J. Roentgenol. **50**:469-479 (Oct.) 1943.

371. Barns, H. H. F.: March Fracture of the Metatarsal Bones, Brit. M. J. **2**:608-609 (Nov. 13) 1943.

372. Berkman, E.: Etiologic Possibilities of March Fractures, J. Bone & Joint Surg. **25**:206-207 (Jan.) 1943.

third metatarsals was involved. In 13 cases the fractures occurred in new recruits, who had not been inducted over three weeks. Pain, lameness and swelling developed during the march or within ten to twenty-four hours. In all cases army shoes that were stiff and rigid were worn, and some loss of voluntary dorsiflexion was evident. Long hikes and stiff army shoes, preventing the proper take-off, produce a strain on the metatarsal heads predisposing to this type of fracture. The increased length of the second and third metatarsal bones and the added weight which they bear offer some evidence as to why the fracture so frequently involves these bones.

Sweet and Kisner,[373] from the American military medical service, discuss the cause, diagnosis, symptoms and treatment of march foot. Three rather typical case reports are included. Recommended treatment consists of immobilization in plaster for four to eight weeks followed by active physical therapy for another two to three weeks.

Swart [374] calls attention to the fact that the pregnant woman provides almost ideally the circumstances which predispose to march fracture. He points out, however, that he was unable to find any case in the English literature in which the condition was found in a pregnant woman; he reports a case of march foot in a woman seven months pregnant. He recommends fixation in plaster, with the use of a walking iron cast after a few days.

Healing of Fractures.—Vance and Wyatt [375] present a comprehensive discussion of the healing of fractures in those locations in which there is no external callus. They discuss the method of healing of ordinary fractures, dividing it into stages, as follows: (1) hemorrhage in and about the fracture, (2) decalcification and resorption of devitalized bone, (3) ingrowth of granulation tissue about the fracture, (4) formation of osseous and cartilaginous matrix, (5) calcification and organization of matrix to form bony union and (6) shaping of the new bone to its final contour. They discuss at some length the criterion for determining nonunion in the absence of external callus and emphasize the fact that there is no standard time for healing of fractures. [Ed. Note (D. H. O.).—This is a worth while article concerning a subject of extreme importance, which has been neglected. The authors go into detail, and this article merits careful study.]

Solandt, Partridge and Hunter,[376] by experimental work on rats, attempted to determine the effect of muscular sensitivity caused by skeletal fixation of the joint. They noted that in the early stages of skeletal fixation, the atrophy and hypersensitivity to acetylcholine were similar to such reactions caused by loss of nerve supply but that the extent of reaction was much less. [Ed. Note (D. H. O.).—This is an interesting subject for experimentation, but much remains to be done before any conclusion can be drawn.]

In an attempt to determine the comparative rates of absorption and callus-stimulating properties of autogenous bone, beef bone, ivory and cow horn, Hughes [377] performed a series of experiments in which the various materials were implanted in femurs of dogs and rabbits. Roentgen and microscopic studies were made and the results tabulated. It was decided that substances located within the medullary canal were absorbed more rapidly than those within the cortex; substances which were extracortical were absorbed most rapidly. Absorption of the extracortical portion of autogenous and beef bone pegs was perceptible after one month. Absorption of ivory pegs was seen after six months and of cow horn pegs after nine months. Autogenous and beef bone pegs showed microscopic evidence of union with the host bone, whereas ivory and cow horn pegs did not. It was concluded that beef bone is a much better substitute for autogenous bone grafts than ivory or cow horn.

Krockert [378] reports on research on the influence of vitamins on the healing of bone. Rabbits in which the right forelegs had been broken were given as a supplement to the standard daily diet vitamins A, B, C and D. Roentgenograms were made on the fourth, thirteenth and twenty-first day after operation. Vitamin A seemed to have no beneficial effect on the healing process and perhaps even delayed the formation of callus. Vitamins B and C had a favorable effect on consolidation of the fracture and on

373. Sweet, H. E., and Kisner, W. K.: March Fractures, J. Bone and Joint Surg. **25**:188-192 (Jan.) 1943.

374. Swart, H. A.: March Fracture as Complication of Pregnancy, Am. J. Surg. **59**:602-604 (March) 1943.

375. Vance, R. G., and Wyatt, G. M.: Roentgenologic Manifestations of Bone Repair: Healing of Fractures Without External Callus, Am. J. Surg. **59**:404-408 (Feb.) 1943.

376. Solandt, D. Y.; Partridge, R. C., and Hunter, J.: Effect of Skeletal Fixation on Skeletal Muscle, J. Neurophysiol. **6**:17-22 (Jan.) 1943.

377. Hughes, C. W.: Rate of Absorption and Callus Stimulating Properties of Cow Horn, Ivory, Beef Bone and Autogenous Bone, Surg., Gynec. & Obst. **76**:665-671 (June) 1943.

378. Krockert, G.: Is It Possible to Observe on Skiagraphs of Healing Fractures Increased Deposition of Minerals as a Result of Vitamin Therapy? Deutsche Ztschr. f. Chir. **255**:398, 1942; abstracted, Bull. War Med **3**:267 (Jan.) 1943.

the deposition of minerals. The results obtained with vitamin D were not consistent.

Injuries to Joints.—Griffiths [379] discusses rehabilitation after injuries of joints. The joint should be considered an integral part of the whole body, and then a decision should be made concerning how the injury has interfered with working capacity. The disability may be due to loss of movement, loss of stability, loss of sense in the joint or increased pain; each leads to a loss of power. After anatomic reconstruction of the joint, immobilization is secured until primary repair of damaged tissue occurs. During this rest, steps should be taken to insure good circulation of the blood and lymph. The author believes that more stiff joints are due to inadequate return of venous blood than to any other cause. Muscular action is the one great factor which helps maintain return of venous blood, and this may be provided despite the presence of a plaster cast by retaining the tonus of the muscles on both sides of the joint. Massage, faradism and other physical therapy methods are important but subordinate to carefully selected active exercises for the muscles. Activity of the rest of the body is also important. Fear, pain and boredom cause early fatigue, and the exercises chosen should allay all of these obstacles. Light exercises in the gymnasium, physical therapy, games and occupational therapy all prove helpful. In some cases assisted movements are used in which the force of gravity is eliminated, i. e. exercises in the swimming pool or on the ground. When the working capacity of the patient has returned, only harm is done by continuing special therapy.

Pugh [380] advises open reduction and fixation with a wire or nail for trimalleolar fractures of the ankle. [Ed. Note (W. G. S.).—This may be necessary for old fractures, but with fresh fractures the fragments can be replaced by traction and manipulation of the foot into dorsiflexion.] For fractures of the carpal scaphoid, skin-tight plaster fixation for four to five months is advised. For uncomplicated injuries of the joints, traction and early motion are recommended, to prevent late arthritic changes.

In a discussion of the treatment of compound injuries of bones and joints, Dickson [381] states that the first objective should be to convert the compound fracture into a closed fracture as rapidly as possible, the best possible alinement of the ends of the bone being maintained in the meantime. With old infected compound fractures, the main objectives are to overcome the infection and preserve the position of the bone in anticipation of a subsequent bone graft.

General Treatment of Fractures.—The regular annual report [382] of the fracture service at the Mayo Clinic for 1942 shows that 1,017 fractures were seen, 500 fresh fractures and 517 old fractures. Only 86 operations were performed in the entire group of fresh fractures. In the group of old fractures, 79 operations were carried out. The mortality rate was the same as in five previous annual studies of the experience of the Mayo Clinic.

Stuck and Venable [383] review the history of their introduction of vitallium into the field of internal fixation and list some of the many different applications of this alloy, not only in the treatment of fractures but in the replacement of tissue, such as vitallium cups for arthroplasty, replacement of the upper end of the femur with vitallium and vitallium skull plates. They call attention to the fact that vitallium has been successfully used for bile duct tubes, ureter tubes and colostomy plugs. [Ed. Note (D. H. O.).—This is an interesting review of the development and use of vitallium in many fields.]

Hughes [384] contends that since many communities have been deprived of their specialists the remaining physicians will have to be versatile. He lists the standard method of emergency treatment of fracture, which consists of temporary dressing and splinting, treatment of shock, administration of tetanus antitoxin, local application of sulfanilamide, local or general anesthesia for reduction, irrigation, débridement and plaster fixation. If x-ray equipment is not available, the percussion method of diagnosis of fracture may be used. With a stethoscope on the bone, the conduction waves indicate the condition of the bone. A list of improvised instruments is given for wiring or plating fractures. The author suggests that general practitioners should not attempt to use Smith-Petersen nails or Kirschner wire countertraction.

Magnuson [385] points out that complicated devices for traction cause the fundamental principles

379. Griffiths, H. E.: Rehabilitation of Joint Injuries, M. Press **209**:166-168 (March 17) 1943.

380. Pugh, H. L.: Injuries of Bones and Joints, Bull. Am. Coll. Surgeons **28**:130-132 (June) 1943.

381. Dickson, F. D.: Injuries of Bone and Joints, Bull. Am. Coll. Surgeons **28**:137-138 (June) 1943.

382. Young, H. H.: Fracture Report for 1942, Proc. Staff Meet., Mayo Clin. **18**:426-427 (Nov.) 1943.

383. Venable, C. S., and Stuck, W. G.: Clinical Uses of Vitallium, Ann. Surg. **117**:772-782 (May) 1943.

384. Hughes, T. J.: Some of the "Do's and Don'ts," with Special Reference to Rural Practitioner Whose Burden and Responsibility Will Be Increased by Present Emergency, Virginia M. Monthly **70**:187-192 (April) 1943.

385. Magnuson, P. B.: Simplicity in Fracture Treatment, Bull. Am. Coll. Surgeons **28**:135-137 (June) 1943.

of traction, countertraction and manipulation to be overlooked in the treatment of fractures. Each fracture must be treated in the manner best suited to it, and this can often be accomplished by simple bandages and traction loops. The author presents photographs showing traction being applied to fractures of the forearm, arm and leg with most elementary equipment.

Venable [386] presents a brief description and illustrations of an inexpensive, light, adjustable, wooden traction splint for either extremity. It may be adjusted to occupy little space for storage. [ED. NOTE (R. B. R.).—This seems an excellent substitute for any emergency splinting agency which cannot keep itself provided with regulation Thomas splints.]

Pathologic Conditions Associated with Fractures.—Clark [387] reports the case of a soldier who received a blow on the right leg which resulted in a fracture of both bones in the middle third of the leg. Immediately there were severe pain and decreased circulation to the leg and foot, which finally caused gangrene and required amputation. [ED. NOTE (W. G. S.).—Reflex traumatic arterial spasm is rare. This is fortunate because it is attended by such severe symptoms that drastic treatment is required. Hermann, of Cincinnati, and Thomson, of Lincoln, Neb., have described the condition thoroughly and pointed out the probable causes. It is probably related to reflex post-traumatic atrophy of bone ("Sudeck's"), which is often seen after relatively trivial sprains of the wrist and ankle.]

Meyer, Friedmann and Ginsberg [388] report a case in which a woman 52 years old, while under treatment for myelogenous leukemia, sustained a pathologic fracture of the right femur. When it is remembered that leukemia is a diffuse hyperplastic process involving all the marrow-containing bones, it is readily understandable that fracture should occur. Moreover, routine skeletal examinations of patients with chronic leukemia would undoubtedly reveal changes in the cortical structure of the long bones that predispose to fractures.

Cash and Hoekstra [389] believe that the introduction of electric shock has been a decided improvement in the management of mental disorders but its traumatic hazards have not been eliminated. Traumatic complications include involvement of the viscera in the form of petechial hemorrhages as well as fractures of the long bones and vertebrae. The authors feel that a safe and effective means of eliminating trauma incident to shock therapy is available in curare. In 139 patients receiving combined curare–electric shock treatments, there were no traumatic complications, and only 1 death occurred.

386. Venable, C. S.: Adjustable Traction Splint for Upper or Lower Extremity, Am. J. Surg. **59**:455-457 (Feb.) 1943.

387. Clark, C. W.: Traumatic Arterial Spasm, Brit. M. J. **2**:167 (Aug. 7) 1943.

388. Meyer, L. M.; Friedmann, A. B., and Ginsberg, V.: Infiltration of Bone with Spontaneous Fracture in a Case of Chronic Myelogenous Leukemia, Arch. Surg. **46**:514-517 (April) 1943.

389. Cash, P. T., and Hoekstra, C. S.: Preliminary Curarization in Electric Convulsive Shock Therapy, Psychiatric Quart. **17**:20-34 (Jan.) 1943.

X. CONGENITAL DISLOCATION OF THE HIP

PREPARED BY A. BRUCE GILL, M.D., PHILADELPHIA

Badgley [390] reviews the theories of the cause of congenital dislocation of the hip and discusses the syndrome of arthrogryposis multiplex congenita. He concludes that the essential feature for his thesis is the evidence of a primary anterior displacement of the head associated with external rotation of the femur. Failure of normal rotation of the limb bud during embryologic life results in anteversion of the head and neck of the femur. Anteversion of the head produces the flat socket. The neck of the femur lies against the posterior rim of the socket, with the greater trochanter posteriorly. Hypoplasia of the posterior rim results from this faulty pressure. The flat socket does not maintain the head in position. A gradual posterior displacement of the head and neck occurs as a result of the greater posterior angle of the os innominatum and the pull of the gluteal muscles.

Gill [391] analyzes and records his observations on the treatment of congenital dislocation of the hip over more than twenty-five years. Dislocation of the hip should be considered to be "cured" only when there has been perfect restoration of anatomic structure. After bloodless reduction there may be an absence of symptoms for many years (in 1 case twenty years) without

390. Badgley, C. E.: Correlation of Clinical and Anatomical Facts Leading to Conception of Etiology of Congenital Hip Dysplasias, J. Bone & Joint Surg. **25**:503-523 (July) 1943.

391. Gill, A. B.: End Results of Bloodless Reduction of Congenital Dislocation of the Hip, J. Bone & Joint Surg. **25**:1-40 (Jan.) 1943.

perfect anatomic restoration. Eventually pain, limp and tire on use appear. Anatomic restoration may take place within several years after reduction, or it may be delayed as long as ten or twelve years. Reduced hips that are symptom free should be kept under observation, and roentgenograms should be taken at regular intervals. The patients should not be discharged as cured until the acetabulum and the head of the femur have become normal. Dysplasia (defect in growth) of the acetabulum is the chief cause of subluxation or complete luxation of the hip subsequent to reduction. The earliest indication in the roentgen films of upward displacement of the head of the femur, whether it appears early or late (even as late as ten or fifteen years after reduction), demands a surgical operation to reconstruct the acetabulum. Outward displacement of the head of the femur, provided there is no upward displacement, is not an indication for surgical intervention, as the hip may eventually become normal. Dysplasia of the head of the femur (delay in its development and its calcification) is of less importance than dysplasia of the acetabulum. But defective calcification (which is not Legg-Perthes disease) is probably an indication that weight bearing should be prevented or restricted until the epiphysis of the head has attained a uniform density. The author no longer does a "shelf operation" on children under 5 years of age if upward displacement occurs when the leg is brought to the longitudinal axis of the body but holds the head down and pointing into the socket by means of an abduction brace. If upward displacement, with the extremity in this position, persists until the child is 5 years of age, the author does not hesitate longer to perform the "shelf operation." The end results of bloodless reduction (or of open reduction also) can be determined only after many years of observation of all dislocations that have been so reduced. Of 126 dislocated hips treated by the author only 14.3 per cent have been proved to be "cured." However, not all of the 126 remained under observation long enough to determine that perfect anatomic restoration occurred. Sixty-five and three-tenths per cent of 98 dislocated hips which were under observation from two to twenty years were proved to be unsuccessfully reduced. The successful reductions may be assumed to be 34.7 per cent. Therefore, the number of successful reductions ("cured") must be somewhere between 14.3 and 34.7 per cent. The statistics of authors who formerly estimated their successful reductions to be 60 per cent or more were false, because their cases were not kept under observation a sufficient number of years to determine the true end results. The records demonstrate that many hips may remain satisfactorily reduced (symptom free) for many years but eventually are proved to be subluxated. Approximately two thirds of the redislocations occur during the first two years following a bloodless reduction and the remaining third during the subsequent years (in 1 case twenty years after reduction). Bilateral dislocations, if they can be reduced, give as high a percentage of cures as unilateral dislocations. Of 24 hips (12 cases), 7 became perfect (cured). The author emphasizes the importance of long-continued observation of all cases of congenital dislocation that have been reduced by the bloodless or by the open method. Subluxation should be recognized, as it is indicated by the appearance of symptoms, and it should be treated by an operative procedure to make an acetabulum as nearly like a normal acetabulum as is possible. Until perfect anatomic structure and relation have been attained, the congenital dislocation cannot be considered as "cured," no matter how perfect the function. The paper is illustrated with many roentgenograms which demonstrate the statements made by the author.

In cases of irreducible congenital dislocation of the hip subtrochanteric osteotomy, devised by Lorenz and by Schanz, is a recognized procedure, although it is not uniformly successful in relieving the symptoms. Hass [392] has found valuable a method of osteotomy for pelvic support with which, by using a locking subtrochanteric osteotomy and displacing the lesser trochanter into the acetabulum, he has secured good stability and freedom from pain as well as an adequate range of motion. The procedure is indicated for supracotyloid dislocations but can also be employed for dislocations of the ilium at a high level after preliminary skeletal traction. Eighteen patients, of whom 4 had bilateral dislocations, have been treated by this method. The author finds the end results to be better than those obtained by other methods of treatment.

Elsner [393] describes 3 cases of geniune congenital dislocation of the hip, in 2 of which the deformity could definitely be classified as teratologic, whereas in the third case it was neither a teratologic dislocation nor a so-called con-

392. Hass, J.: A Subtrochanteric Osteotomy for Pelvic Support, J. Bone & Joint Surg. **25**:281-291 (April) 1943.

393. Elsner, W.: Question of Genuine Teratologic, Congenital Dislocation or Intra-Uterine, Traumatic Luxation, Ztschr. f. Orthop. **73**:193-200, 1942.

genital dislocation. He suggests in this case an intrauterine traumatic origin. The case is compared in detail with cases of teratologic dislocation of the hip, which is discussed thoroughly.

Hein [394] presents a series of 87 cases in which serial roentgen study was made of infants born in definite breech presentation. In 4 of these cases, or 4.59 per cent, the infants had congenital dislocation of the hips. Attention is drawn to the high incidence of congenital anomalies and twin births in the families and among the children themselves. It would seem that antenatal forced position due to deviation of the position of the fetus may play some part in congenital dislocation of the hip, but no general conclusions are permissible. The studies are to be continued.

Ottolenghi [395] reports briefly 7 cases of tibial transplantation for reconstruction of the roof of the cotyloid cavity. He concludes that the iliac osteoplastic shelf method of repair of the roof of the cotyloid cavity in children fails in a high percentage of cases and that much better results are obtained with a tibial graft. Twenty-one figures show roentgenograms indicating the results of operation in the cases cited.

Platt [396] reviews the history of congenital dislocation. Manipulative reduction is discussed, and the need for gentleness is stressed. He analyzes his personal experience with 50 patients who have been followed for over ten years. Of 62 hips, 46 are reported as functionally satisfactory and 29 as anatomically good. The causes of failure are divided into (1) extrinsic causes—bad selection of cases, choice of wrong method or inefficient after-treatment; (2) intrinsic causes—anomalies of the joint capsule and skeletal anomalies, including osteochondritis. He points out that residual subluxation calls for further treatment by either the closed or the open method. Open reduction is indicated for: (1) young children when there is evidence that the intrinsic obstacles to reduction are formidable; (2) older children when closed reduction is obviously impracticable; (3) residual subluxations following closed reductions. The use of the divaricator in the first year of life is described.

Sutherland and Rowe [397] make use of a metal prosthesis to replace a deficient superior acetabular margin in a subluxating hip. A short lateral longitudinal incision is made. The gluteal muscles are split above the greater trochanter in the line of their fibers, and a small area of the ilium above the acetabulum is exposed. A small metal shelf is applied and held in place with screws. No cast is used, and motion of the hip is begun early. The advantages of this procedure over shelf operation are cited: (1) No arthrotomy is performed, and thus no ankylosis occurs; (2) no stripping of the gluteus medius and minimus muscles is done, and so no weakness of abductor muscles occurs; (3) it is less shocking, because less blood is lost, osteotomy is not performed and the operating time is less. Three cases are reported.

Whiston [398] reports a series of 48 cases of congenital dislocation of the hip observed from seven to eighteen years after reduction. The cases are classified and tabulated according to technic followed, roentgen studies, complications and type of dislocation present. It is noted that (1) patients under the age of 5 years treated by closed reduction presented results superior to those in older age groups; (2) a postreductive immobilizing period extending over ten months produced more cures in this age group than when a shorter period of fixation was used. Complications encountered are recorded.

394. Hein, R.: Relation Between Breech Presentation and Congenital Dislocation, Ztschr. f. Orthop. **73**: 165-193, 1942.

395. Ottolenghi, C. E.: Technic of Reconstruction of Roof of the Cotyloid Cavity in Children: Question of Iliac Osteoplastic Shelf or Tibia Graft, with Report of Cases, Bol. y trab., Soc. argent. de cirujanos **4**:307-325, 1943.

396. Platt, H.: Congenital Dislocation of Hip, Brit. J. Surg. **30**:291-304 (April) 1943.

397. Sutherland, R., and Rowe, M. J., Jr.: Metal Shelf for Hip Dislocation, Am. J. Surg. **62**:206-210 (Nov.) 1943.

398. Whiston, G.: Congenital Dislocation of Hip with Special Attention to After-Care Period and Late Postreductive Results, Surg., Gynec. & Obst. **77**:307-314 (Sept.) 1943.

XI. CONDITIONS INVOLVING THE SPINE AND THE THORAX

PREPARED BY JOHN R. COBB, M.D., NEW YORK

Anatomic Variations.—In an interesting and beautifully illustrated paper, Ehrenhaft [399] describes the development of the vertebrae and the intervertebral disks and correlates developmental peculiarities with certain lesions found in later life. He believes that an understanding of the blood supply and its fate is of special importance for the understanding of the later development of the intervertebral disk and states:

> The explanation of some of the nucleus pulposes into the spongiosa of the vertebral bodies occurring at an age when the senescent degenerative changes of the

399. Ehrenhaft, J. L.: Development of the Vertebral Column as Related to Certain Congenital and Pathological Changes, Surg., Gynec. & Obst. **76**:282-292 (March) 1943.

cartilaginous plates are only minimal can be based on it. The intervertebral disc is constantly exposed to more or less severe trauma and it is one of the earliest structures to show definite senescent changes. This is partly explainable on the development and the early regression of the vascular supply.

After a careful description of the blood supply, the author states:

Regression and scarring starts shortly after birth and slowly progresses to completeness by the age of 18 to 25 years, at which time most of the growth has stopped and the bony ring epiphysis has fused with the vertebral bodies proper. Where those vessels have penetrated the cartilaginous plates some chondrification gaps result. These are replaced at the time of complete degeneration of the vessels by either cartilaginous plugs or by scar tissue and sometimes by calcification. They form areas of lessened resistance to the increased turgor of the semisolid intervertebral disc substance especially if the disc is subjected to increased pressure.

Ehrenhaft's finding of no elastic tissue fibers within the annulus during embryonic life or in an 18 month old child differs from the observations of some other investigators.

The author points out that developmental defects of the spinal column have been poorly understood and that one has to differentiate between the malformations occurring in the vertebrae—column of intervertebral disks—and those along the neural column, formed by the neural arches. He believes that the latter malformations have a close relationship with developmental defects of the neural tube. He also feels that not all developmental defects in the vertebrae—disk column—can be explained on the basis of malformations in the mesenchymal and cartilaginous embryonic states, though many become easily understandable if one considers the vascular supply and the changes which occur in the notochord during the different stages. He discusses the cause and formation of congenital deformities of the spine.

There are considerable confusion and misunderstanding regarding the problem of juvenile kyphosis, and Ehrenhaft's discussion on this seems worth quoting:

Multiple spongiosal nuclear prolapses with juvenile kyphosis in the young adolescent groups occur mostly in boys subjected to very heavy manual labor. One must keep in mind that at this age there is still good blood supply to the intervertebral disc tissue and not all the vessels have degenerated. The nucleus pulposus is still rather liquid and easily displaced. Scheuermann, basing his observations and this theory only on x-ray findings, states that the deformity is due to an aseptic necrosis —an "epiphysitis" of the ring epiphysis which is undergoing marked ossification at about this age. Schmorl and since then others have examined, at autopsies, numerous spines of adolescent patients with juvenile kyphosis, and they found large nuclear prolapses into the spongiosa through the cartilage plates. These prolapses are in a location which is usually the one where some of the chondrification gaps have occurred due to degenerated vessels producing weak points. It also has been proved fairly conclusively that the ring epiphysis has nothing to do with the growth in the height of the vertebral bodies. This growth in the height is exclusively a function of the cartilage plate which is central to the ring epiphysis and underlies the rim ledge proper. Nuclear prolapses of juvenile kyphosis often occur all along the vertebral bodies of the lower thoracic and upper lumbar region. The uneven growth in height of individual vertebrae tends to retard the growth anteriorly where the increased pressure load is concentrated. More normal growth occurs posteriorly. Thus, the relative wedging of the vertebral bodies is secondary to the improper mechanical function of the degenerating narrowed intervertebral disc. In this way the kyphotic deformity results. The fragmentation of the anterior portion of the ring epiphysis seen in x-ray pictures results from improper motion, abnormal pressure relationship, and shearing stress put upon the anterior annulus fibers and the unfused ring epiphysis.

[ED. NOTE.—This is an excellent article and should be read by every one interested in spinal lesions. The author's explanation of the cause of juvenile kyphosis is especially interesting in contrast with the theories of those who believe that it is caused by epiphysitis or some glandular or vitamin deficiency. While he does not discuss treatment, his theory certainly adds considerable emphasis to the importance of rest in recumbency and avoidance of fatigue, heavy labor or violent physical effort by adolescents with juvenile kyphosis. In the light of this theory, the use of spinal braces to reduce stress and strain on the involved vertebrae and the consideration of earlier spinal fusion in the area of the wedged vertebrae may be indicated more frequently for adolescent kyphosis than has been practiced by most orthopedic surgeons.]

Romanes [400] reports a study of the spinal cord of a newborn child whose right lower limb was missing from the knee joint distally. He found a distinct reduction of the right side of the spinal cord in the lumbosacral region. This affected the posterior column, the root of the sacral plexus and the posterior and anterior horns of gray matter, the anterior horn showing almost total loss of the posterolateral and the postposterolateral column of motor cells, which supply the nerves to the leg and foot. The loss of these columns of cells of the anterior horn is considered to be the result, not the cause, of the developmental insufficiency of the peripheral mesoderm. The author points out that while these findings are valuable in determining central peripheral relations of the spinal cord and the muscles of the limbs, they throw no light on the mechanism of development.

400. Romanes, G. J.: The Spinal Cord in a Case of Congenital Absence of Right Limb Below the Knee, J. Anat. **77**:1-5 (Oct.) 1942.

Moreton [401] discusses the problem of basilar invagination and reports a study of a series of 139 cases, in 41 of which associated congenital changes were present in the cervical portion of the spinal column and in 98 of which such changes did not exist. In conclusion he states:

1. Persons who have basilar invagination, as diagnosed by means of Chamberlain's line, may go through life without symptoms. 2. Diagnosis depends on closer association of clinician and roentgenologist. Such association will aid detection of the condition in cases in which other diagnoses have been given. 3. Associated congenital anomalies, especially of the upper cervical vertebrae, are important in increasing the chances of this condition manifesting itself clinically. If these congenital changes exist, the manifestations usually occur at an earlier age than that at which they occur if the changes do not exist. 4. Basilar invagination may cause symptoms without there being a definite increase in the basilar angle. 5. Patients with basilar invagination secondary to Paget's disease may show symptoms of the primary disease only. 6. Treatment is decompression.

Eaton [401] discusses Moreton's paper and stresses the importance of differential diagnosis. He feels that the paper by Chamberlain on platybasia must be given credit for stimulating interest in congenital malformations in the region of the foramen magnum. Since its publication clinicians have been reluctant to classify certain conditions as multiple sclerosis, syringomyelia, familial cerebellar ataxia and tumor of the brain or of the upper cervical portion of the spinal cord without careful roentgenographic study to exclude bony malformations in the region of the foramen magnum, which may produce a somewhat similar clinical picture.

Eaton also states:

The symptoms produced are not difficult to remember if the structures affected are kept in mind. The medulla and spinal cord join at the level of the foramen magnum. If the foramen is narrowed by a congenital malformation which allows the odontoid process to dislocate posteriorly, signs of compression of the upper cervical portion of the cord result and spastic weakness of the legs and arms with Babinski and other signs of pyramidal involvement may be produced. Nystagmus, absent abdominal reflexes, paresthesias, ataxia and inco-ordination may be present also. Furthermore, remissions and exacerbations occur. One can readily understand why with such a clinical picture the condition may be confused with multiple sclerosis.

Diagnostic Signs.—The linear thoracic paraspinal shadow which is often seen in anteroposterior roentgenograms of the chest has been hard to explain. In the solution of this problem, Brailsford [402] and Garland [403] independently refer to an editorial in *Radiology*, August 1942, page 229, which draws attention to the following:

A slender vertical line of demarcation is often seen in anteroposterior or sagittal roentgenograms of the bony thorax and upper abdomen. This line lies on the left side of the lower two-thirds of the thoracic spine and sometimes continues as far down as the plane of the first two lumbar segments. . . . It is not visible on all films or projections of this portion of the body but is observed with such frequency that it must be the result of variation in the course or position of a normal structure situated therein.

Both Brailsford and Garland believe that this line is the border of the lung. After a discussion of the anatomic considerations, Brailsford emphasizes the line as an important diagnostic sign.

It shows the close relation of the medial border of the lung to the lateral surface of the vertebral body. If the latter is crushed its transverse diameter will be increased and the medial border of the lung will be displaced to that extent laterally. If the fracture is associated with a paravertebral haematoma this will show as an added expansion and further lateral displacement of the medial border of the lung. The antero-posterior radiographs show this as a fusiform expansion of the medial opacity, for the postero-medial border of the right lung will be similarly displaced. In a case which came to court the existence of a crush fracture of the vertebral body was disputed until the presence of a paravertebral haematoma was demonstrated to the judge on the radiograph taken a fortnight later. But the commonest demonstration of lateral displacement of the postero-medial border of the lung is due to the paravertebral tuberculous abscess. It is important because it may be detected before any change in the bone has become apparent. The abscess may extend the whole length of the dorsal spine, is usually fusiform in shape, and is sometimes of the width of the heart shadow; indeed, it has occasionally been missed because it was mistaken for the latter. It may show progressive expansion from the time it is first detected. Because from the level of the reflection of the pleura on to the diaphragm there is below no contrast in the densities of the adjacent tissues, the outline of the abscess cannot be traced in the abdomen—i. e., we are dependent upon the lateral displacement of the posterior-medial border of the radiotransparent lung for visualization of the abscess. Consequently, though the abscess may have arisen from caries of one of the lumbar vertebrae, if no bone changes are yet recognizable its origin may not be apparent.

Because of this common appearance of the dorsal tuberculous paravertebral abscess there is a tendency to diagnose all fusiform deviations of the postero-medial border of the lung as tuberculous in origin, but appreciation of the anatomical features I have described which give rise to these shadows induces further discrimination. Thus neoplasm, both primary and secondary, may cause collapse and an increase in the transverse diameter of the diseased vertebral body; this will cause a lateral deviation of the postero-medial border of the lung, which will be increased, if there is proliferation of neoplastic cells or if associated with haemorrhage, to such an extent that it may resemble a paravertebral abscess. It should be remembered, however, as a feature in differential diagnosis, that neoplasm appears to spare the disks even though all the vertebral body is destroyed.

Fusiform paravertebral expansions have been seen at the site of pneumococcal, typhoid, and paratyphoid

401. Moreton, R. D.: Basilar Invagination: So-Called Platybasia, Proc. Staff Meet., Mayo Clin. **18**: 353-357 (Sept. 22) 1943.

402. Brailsford, J. F.: The Radiographic Postero-Medial Border of the Lung or the Linear Thoracic Paraspinal Shadow, Brit. M. J. **1**:219-220 (Feb. 20) 1943.

403. Garland, L. H.: The Postero-Mesial Pleural Line, Radiology **41**:29-33 (July) 1943.

abscesses. In these the destructive changes are more frequently present in the disk, which appears to collapse, and within a few weeks the postero-medial border of the lung is straightened out again. The vertebral bodies ultimately fuse. In the acute phase of vertebra plana the involved body is surrounded by fusiform expansion, which within a few weeks gradually disappears, leaving the disk apparently intact but the elements of the vertebral body compressed to a quarter or a third of the normal depth. In Paget's disease that is localized to one or more dorsal vertebral bodies the postero-medial border of the lung is deviated laterally by the expansion of the bodies. In osteochondritis of the spine in infants and adolescents some degree of thickening of the tissues adjacent to the vertebral bodies occurs, and the medial border of both lungs may become apparent just lateral to the border of those bodies; but in this there is no localized fusiform expansion.

In one case rupture of the posterior wall of the aorta was associated with haemorrhage into the areolar tissue surrounding the vertebral bodies: an appearance simulating a paravertebral abscess was produced. Any inflammatory or neoplastic proliferation within the vertebral body or the areolar tissue surrounding it may produce changes such as have been described, and it may be necessary to seek elsewhere for a clue to the identity of the organisms and cells producing the displacement of the lung. Empyema localized to this site would also push the lung laterally.

[ED. NOTE.—Undoubtedly many orthopedic surgeons have been confused by this "posteromesial pleural line," and it seems worth while to draw attention to its diagnostic significance.]

Roentgenographic Technic.—Gunson [404] discusses the anatomy of the sternoclavicular articulation and the roentgenographic technic to visualize this area adequately. He describes six projections for visualization of the sternoclavicular joint.

Judd [405] points out that there are occasions when satisfactory views of the odontoid process of the axis are difficult to demonstrate with the routine anteroposterior views taken through the open mouth. For a modified occipitomental projection he places the patient in the prone position, the head adjusted so that the chin is resting on the table and the nose is 1¼ inches (3 cm.) from the table top. The x-ray tube with a small cone should be centered so that the central ray, at right angles to the film, will pass through the vertex of the skull and the foramen magnum. The resultant roentgenogram will show the odontoid process framed in the foramen magnum. This projection is not intended to supersede the routine anteroposterior view but is recommended when satisfactory films are unobtainable by the usual methods.

Surgical Operations on the Spine.—Local infiltration anesthesia induced with a procaine hydrochloride solution containing epinephrine hydrochloride is the anesthesia preferred by Freiberg and Perlman [406] for most spinal operations, including fusions, laminectomies and combined procedures. They suggest that induction of anesthesia be preceded by administration of a barbiturate, to act as a mild sedative but primarily to prevent reactions to procaine. In their last 17 cases as excellent an anesthetic effect was obtained with only 0.5 per cent solution of procaine hydrochloride with epinephrine as with equal amounts of a 1 per cent solution. They report only 1 instance of apparent allergic or hypersensitive reaction to procaine in several hundred cases in which infiltration anesthesia was employed and a satisfactorily low incidence of complications in a series of 54 spinal operations from 1939 to 1942. The authors feel that the disadvantages of and the contraindications for the use of local infiltration anesthesia are few, but the psychoneurotic patient, the patient speaking only a foreign language or the patient who expresses a definite objection to this type of anesthetic should be given a general anesthetic. The preoperative medication consisted of administration of a barbiturate, preferably pentobarbital sodium, ¾ to 1½ grains (0.05 to 0.09 Gm.) at bedtime and again one to two hours before operation and morphine with atropine or scopolamine about a half-hour before operation.

Procaine was also used for removing the tibial graft. After the skin and subcutaneous tissues were infiltrated and before the periosteum was exposed or the skin incised the fine gage needle was inserted to the underlying bone and at 1½ inch (3.8 cm.) intervals about 1.5 cc. of procaine hydrochloride solution was injected. No further infiltration was required for osteoperiosteal grafts, but when full thickness grafts were cut some pain was felt when the endosteum was encountered. In recent cases the authors injected 1 or 2 cc. of procaine hydrochloride solution into the tibial medullary canal through small drill holes at the extremities of the site of the proposed graft, the hub of the short needle occluding the osseous holes during injection. This intramedullary injection of procaine induced complete anesthesia or made the pain negligible.

[ED. NOTE.—There are certain definite advantages of local infiltration anesthesia for spinal operations. However, while gentleness is desirable one usually does have to proceed more slowly

404. Gunson, E. F.: Radiography of Sternoclavicular Articulation, Radiog. & Clin. Photog. (no. 1) **19**:20-24, 1943.

405. Judd, G.: A Useful View of the Odontoid Process of the Axis Vertebra, Radiography **9**:46-47 (June) 1943.

406. Freiberg, J. A., and Perlman, R.: Local Infiltration Anaesthesia in Spine Surgery, J. Bone & Joint Surg. **25**:145-152 (Jan.) 1943.

with local than with general anesthesia, and when a long area is to be fused it may be necessary to do the operation in several stages with local anesthesia, while the whole area might be fused in one stage with general anesthesia. If general anesthesia reduces the number of operative procedures, it would seem preferable to local anesthesia, though there is no doubt that local anesthesia is best in certain cases, and it should be used more generally.]

Howorth [407] discusses the various stages and procedures in the development of spinal arthrodesis. In discussing the early period of development of the fusion operation, he states:

> Despite the several technics described, this early period was marked not so much by study of the technic of spinal fusion, as by discussion as to whether spinal fusion was justified at all. . . . It was found, over a period of years, that growth of the spine continued at the normal rate after fusion, and that the trunk-leg ratio remained the same in these patients as in normal individuals, allowing for the effect of the kyphos.

[ED. NOTE.—It should be pointed out that the vertebral body which is involved by tuberculosis is frequently deformed and does not grow normally, since its growth centers are involved. One therefore would not expect fusion of the posterior element to disturb appreciably the alinement in the fused area. It should be stressed, however, that in some cases of scoliosis the vertebral bodies do continue to grow while the fused posterior portion of the spine is retarded or stationary. This is especially true for patients with scoliosis following poliomyelitis. A number of cases have been studied and reported in which there was a definite posterior concavity in the fusion area following spinal fusion for scoliosis in children who continued to grow, although this work has not yet been published.]

Howorth discusses the application of spinal fusion to other conditions besides tuberculosis and scoliosis and summarizes the indications for operation as follows:

> 1. Tuberculosis: The treatment of choice at all ages, unless complete spontaneous natural fusion can be demonstrated, or the general condition of the patient or complications preclude the operation.
>
> 2. Scoliosis: In children with rapidly progressive deformity, or deformity with decompensation which can be corrected sufficiently to warrant fixation; in adults occasionally for relief of pain.
>
> 3. Spondilolisthesis: All cases in the lower lumbar region unless contraindicated by age or the general condition of the patient.
>
> 4. Other lumbosacral anomalies: Pain of long duration, of moderate or great intensity, frankly due to the anomaly and unrelieved by other treatment.
>
> 5. Rupture of nucleus pulposus: Many of these joints are unstable primarily, and should be fused upon removal of the nucleus, preferably without laminectomy.
>
> 6. Compression fracture of the spine and some dislocations: As a means of maintaining reduction, hastening convalescence, and preventing pain.
>
> 7. With laminectomy: When indicated with a coincident orthopedic condition, or an extensive procedure.
>
> 8. Special indications in certain other conditions.

The author also gives a complete description of the operative technic, with illustrations of the various steps in the technic, and feels that denuding the articular cartilages is the most crucial point in the fusion. He also feels that "the chief feature of postoperative care is proper immobilization of the spine by bed rest and a brace or plaster jacket until the fusion has become sufficiently strong to support the weight of the trunk, and ordinary body movements." He states that "those with scoliosis are operated upon through a fenestrated plaster jacket, and the jacket is then reinforced. Other cases have a Taylor brace applied."

[ED. NOTE.—It is interesting to note that many surgeons have obtained satisfactory solid spinal fusion without including the articular facets, and, as Howorth states, "It matters not so much how a particular chip is laid or from whence a particular fragment of bone comes, but as to whether fusion is obtained, how quickly and how strong."

There are obviously many variations of the technic for spinal fusion which are satisfactory, and the particular detail depends on the preference and ability of the individual surgeon.

Howorth concludes:

> The effects of the operation should be clearly understood. A fusion may hasten and assure healing of tuberculosis and perhaps sometimes other infections, by completely immobilizing the diseased section of the spine. Progressive deformity due to tuberculosis, scoliosis, and spondylolisthesis may be prevented. The establishment of fusion for this purpose in cases of round back or hemivertebrae is open to question. In scoliosis and fracture, fusion may be the best or only means of maintaining correction of deformity. We do not attempt, and advise against attempting, to correct the deformity in tuberculosis. Fusion may be used for the relief of pain in the lumbosacral anomalies as well as all of the conditions just named. In many cases it may not only aid in the cure of the disease, the arrest or correction of deformity, and the relief of pain, but may be the quickest and most economical method of relief, in this way offering a financial advantage to both patient, hospital, and community. Thus, we see that spinal fusion has evolved during the past 30 years from a "radical" procedure in the treatment of tuberculosis, to a well established operation employed for a number of abnormalities of the spine. It is not a panacea, but in properly selected cases, and in skilled hands, fusion offers little risk and the possibility of great benefit to a large number of patients.

[ED. NOTE.—This is an excellent article and covers the history and development of spinal fusion operations, with twenty-four references on the subject.]

407. Howorth, M. B.: Evolution of Spinal Fusion, Ann. Surg. **117**:278-289 (Feb.) 1943.

Meyerding [408] discusses the results of surgical treatment for spondylolisthesis. He reports a study of 876 cases of spondylolisthesis observed between 1922 and 1940 inclusive, with operations in 143, or 16.3 per cent. The paper is based chiefly on the 143 cases in which operations were performed. He also discusses the coexistence of spondylolisthesis and protrusion of an intervertebral disk and found these two lesions associated in 7 of the 143 cases. The average duration of symptoms before operation was six and three-tenths years, and in most of the cases conservative treatment had failed to give relief.

[Ed. Note.—Many orthopedic surgeons feel that it is not worth while to try conservative treatment for spondylolisthesis when the symptoms are severe and start at an early age, while patients beyond the age of 50 before the onset of symptoms are frequently relieved by an adequate back brace.]

In discussing treatment the author describes the fusion operation which he prefers. In the fusion procedure he includes curetting the articular facets and inserting two grafts from the tibia and sometimes numerous shavings from the tibia. At the end of six weeks the patient is permitted up with a lumbosacral canvas corset in which a steel rectangular leather-covered pad has been sewed. Plaster casts are rarely used. The support is worn from four to six months after operation.

In discussing the results in 118 cases in which follow-up data were available, the author reports that the results were good in 60.1 per cent, they showed improvement in 28 per cent and they showed no improvement in 11.9 per cent. He reports postoperative complications in 14 cases, infection in 8 and phlebitis in 6. There was no operative mortality in any of the 143 cases. The author states that in 87.6 per cent of the 118 cases the patients were able to engage in gainful occupations after operation, and in 66.4 per cent they were able to resume their former occupations.

[Ed. Note.—This is an excellent report on the treatment of spondylolisthesis, with illustrations of the operative technic and numerous tables of statistics. It might be mentioned, however, that many orthopedic surgeons consider it unnecessary to include the third lumbar vertebra in fusions for spondylolisthesis of the fifth lumbar area. If the fusion is solid from the fourth lumbar vertebra to the sacrum there should be no need to include the third lumbar vertebra, although apparently many surgeons still do. It is also noted that the author does not give statistics on the number of pseudarthroses following this method of fusion.]

Toumey [409] describes a method of internal fixation for fusion of the lumbosacral joint.

After a description of the usual method for exposure of the lumbosacral area and removal of the disk if necessary, the author describes the fusion procedure, which consists of removal of the articular cartilage from the lumbosacral facets, insertion of small bone chips into the interval between the facets and insertion of a vitallium screw, 1⅛ inches (3 cm.) long, with coarse threads and Phillips recessed head, through and across the facets, to fix the lumbosacral facets. Additional bone chips from the sacrum are then placed in the small sacral hollow immediately below the facet and extending up over the articulation. The same procedure is then carried out on the other side. The screws are placed to immobilize the lumbosacral joint immediately and to maintain internal fixation until bony fusion of the facets takes place. They are also placed to transfix the facets and enter the large, thick, lateral portion of the first sacral segment.

The patients were kept in bed for three weeks after operation, and while in bed they wore no brace or support. When they became ambulatory, the men wore a canvas lumbosacral belt and the women a corset.

[Ed. Note.—This is an interesting procedure and has definite advantages in fusions of the lumbosacral area. However, in a high percentage of these fusions (especially those done for spondylolisthesis and for a lesion of a disk involving the joint between the fourth and fifth lumbar vertebrae) it is necessary to extend the fusion to the fourth lumbar vertebra or higher, and in these cases there would still be the problem of immobilizing the joints to be fused above the fifth lumbar vertebra. The Wilson spine plate has proved satisfactory for obtaining immediate immobilization of a number of joints at once and can be used for fusion of any number of lumbar vertebra if necessary. A difficulty, however, has been that sometimes the spinous processes on the sacrum have been too small to hold a bolt adequately, so the plate could not be used. This difficulty has been partially solved by the use of J or C bolts around a spinous process too small for drilling for a straight bolt. In some cases in which there is no sacral spinous

408. Meyerding, H. W.: Spondylolisthesis: Surgical Treatment and Results, J. Bone & Joint Surg. **25**:65-77 (Jan.) 1943.

409. Toumey, J. W.: Internal Fixation in Fusion of the Lumbosacral Joint, Lahey Clin. Bull. **3**:188-191 (Oct.) 1943.

process and the fusion has to extend above the fifth lumbar vertebra, it will probably be worth while to combine these two methods and use the Toumey method for immobilization of the lumbosacral area and a Wilson plate to immobilize the joints above.]

Vom Saal [410] describes a method for fusion of the thoracic portion of the spine in which the transverse processes are completely removed subperiosteally and used as additional grafts.

The author feels that "mechanically from this procedure there is a great increase in strength, not only because it nearly doubles the usual fusion width, but also because it provides forward extensions, bringing the fusion mass closer to the axis of the spine." He states that the fusion area produced now resembles a "channel" rather than a rectangular section beam, using a complicated engineering formula to prove this.

The author also states

> The question has been raised whether removal of the rib articulations might not result in rib fusion, with splinting of the chest and respiratory embarrassment. Eight of the fifteen patients whose spines were fused by this method have had careful measurements of the chest and vital capacities, beginning six months before operation and extending to one to three years after operation. In none has the postoperative vital capacity or chest expansion decreased.

Two roentgenograms are included showing extension of the fusion to most of the ribs. Two cases are reported, in 1 of which the vital capacity was 30 per cent of normal and there was almost complete paralysis of all respiratory muscles except the diaphragm; with the constant postoperative use of empyema blow bottles "the vital capacity continued to increase, and is now 60 per cent of normal." In the other case there was obvious inclusion of some of the ribs in the fusion. "In spite of this, the vital capacity increased 20 per cent postoperatively, and the chest expansion has remained the same."

[Ed. Note.—Most orthopedic surgeons are usually able to obtain satisfactory solid spinal fusions in the dorsal area by the Hibbs or the Mackenzie-Forbes method, with or without additional bone, and removal of extra bone from the tibia or iliac crest is not often difficult. It is doubtful whether it is necessary to remove the transverse processes for thoracic spinal fusion, and the desirability of obtaining fusion of the ribs is questionable. In a case of severe scoliosis following poliomyelitis with no motion of the chest and only diaphragmatic and abdominal breathing, obviously fusion of the ribs would not decrease the expansion of the chest and so would not decrease the vital capacity. However, it is usually conceded that motion of the ribs is necessary for expansion of the chest, and in cases of ankylosis of the joints of the ribs with Marie-Strümpell arthritis the patients usually have diminished expansion of the chest. It is difficult to see how there was no decrease in the vital capacity or expansion of the chest postoperatively in any of these cases if the joints of the ribs were fused, as claimed by the author, unless there was no motion of the joints of the ribs before operation. It might be mentioned that the roentgenograms in this article which show "extension of the fusion to most of the ribs" are oblique views, and in an oblique view the shadow of the fusion area is usually thrown to one side, often apparently overlying the ribs. This is especially true after fusion for scoliosis when there is still some residual curve. As a matter of fact, oblique views are usually taken postoperatively for this reason, in order to show the continuity of the fusion area on one side.]

Swart [411] concludes that "the posterior bone graft when properly placed is sufficient to stand any ordinary strain placed on the back." He points out that some authors have stated that the results of the use of posterior grafts for spondylolisthesis were unsatisfactory, which led to the search for a new method. The author presents a case in which compression of the fourth lumbar vertebrae resulted from a fall over a year after spinal fusion for spondylolisthesis, to show that a single posterior bone graft possesses all the strength necessary for solid fixation. In spite of an injury sufficient to cause a compression fracture of the fourth lumbar vertebra the fusion area remained intact.

[Ed. Note.—The fusions for spondylolisthesis obtained by many various methods, including the single posterior graft, are usually satisfactory to stand all normal strains if the procedure is done properly with an adequate amount of bone and a really solid fusion is obtained. Failures of fusion are almost always due to poor technic, inadequate bone in the fusion area or insufficient postoperative immobilization. It might be mentioned, however, that there is an increasing trend toward the use of the various methods employing numerous interdigitating bone chips in slivers rather than one single large bone graft, which depends for its success on its fusion to several spinous processes and frequently does not fuse to one or more of them.]

410. Vom Saal, F.: Thoracic Spine Fusion: A Method, J. Bone & Joint **25**:49-52 (Jan.) 1943.

411. Swart, H. A.: Spondylolisthesis Treated by Posterior Bone Graft: Fracture of Vertebra Above Graft, South. Surgeon **11**:846-848 (Dec.) 1942.

Collins [412] reports a case of unusual fracture of the second cervical vertebra in which the body of the second cervical vertebra was dislocated forward and down in front of the third cervical body yet there was only generalized muscular weakness of the left arm. The patient was treated with continuous traction for one month, and later a neck brace was worn for one year, after which time there were only a moderate decrease in rotation and extension of the head and no abnormal neurologic findings.

Ankylosing Spondylarthritis. — Baker,[413] in discussing ankylosing spondylarthritis, points out that the condition is more common than is indicated in the literature, partly because of the various names under which it has been discussed but probably more because of the frequency of mistaken diagnosis. The author believes that recent reports of excellent results obtained by roentgen therapy have created a new interest in this disease, have made early and correct diagnosis important and have warranted a review of the subject and improvement in orthopedic care if full benefit is to be obtained by combined orthopedic and roentgen ray treatment.

He discusses the early symptoms and the later development of symptoms, the roentgen findings and the course of the disease. He reports most satisfactory results with a combination of orthopedic and roentgen therapy. He describes the method of treatment, which includes rest in bed, hyperextension of the spine, traction if necessary and physical therapy, including heat massage and corrective exercises, with special attention given to securing relaxation of the abdominal muscles. He describes the methods of exercise and an apparatus designed to prevent hyperextension of the lumbosacral area and to aid in the correction of the dorsal curve and the development of the thoracic bundles of the sacrospinal muscles. He also describes an excellent brace for use in these cases. This brace seems to have some definite advantages over other braces which have been used. The author, however, does not say how long the brace should be worn and whether it is used only during the early stage of the disease or during the manifestation of symptoms. He states that the patient's general health has been improved and the sedimentation rate lowered. He, however, admits that too short a time has elapsed to determine whether roentgen therapy is only analgesic or whether it has a deterrent effect on the disease and will serve to prevent further ossification of the ligamentous structures of the spine.

[Ed. Note.—This is an excellent article on combined roentgen and orthopedic therapy of spondylarthritis. The author's three point hyperextension brace is well illustrated and has many practical advantages over most braces used for this purpose.]

Hilton [414] reports 62 cases of ankylosing spondylitis in which roentgen therapy was used. He prefers local application over a small field rather than over a wide field, or the bath technic, which he feels has various grave disadvantages. He believes that it is worth while treating all patients with ankylosing spondylitis, whatever the stage, except when there is complete ankylosis coupled with entire absence of pain, and he recommends combined treatment by a radiotherapeutist and a physical therapeutist as does Baker.[413] He found that changes in the sedimentation rate after treatment are not always parallel to the clinical improvement.

Dassen and Rospide [415] examined 12,000 roentgenograms of the spine taken to detect conditions other than spinal lesions. They reported typical lesions of spondylarthrosis in 140, or 1.6 per cent. Of these, 100 roentgenograms belonged to patients whose recorded clinical history did not show any relation between the observed spondylarthrosis and pains of any kind.

They believe that the evolutive development of spondylarthrosis runs parallel with that of arteriosclerosis and both show the same humoral modifications.

Oppenheimer [416] reports 4 cases of "paravertebral abscesses associated with Strümpell-Marie Disease." He states that the 4 cases had certain points in common. The disease was chronic and began with pain and stiffness in a definite part of the back or neck. In the course of several years, the pain tended to subside and the stiffness increased, but the symptoms remained confined to the region originally affected. Abscesses in the soft tissues of the back or neck were present at the level of but not below the involved vertebrae. Roentgenograms disclosed ankylosing arthritis of the apophysial joints at the level of the abscess of the soft tissue, with ossification of the vertebral ligaments but without

412. Collins, H. L.: An Unusual Fracture of Second Cervical Vertebra, J. Kansas M. Soc. **44**:253-254 (Aug.) 1943.

413. Baker, L. D.: Ankylosing Spondylarthritis, South. M. J. **36**:180-184 (March) 1943.

414. Hilton, G.: Some Observations on the X-Ray Treatment of Ankylosing Spondylitis, Proc. Roy Soc. Med. **36**:608-610 (Sept.) 1943.

415. Dassen, R., and Rospide, P. C.: Asymptomatic Spondylarthrosis and Its Frequency, Medicina, Buenos Aires **3**:275-286 (April) 1943.

416. Oppenheimer, A.: Paravertebral Abscesses Associated with Strumpell-Marie Disease, J. Bone & Joint Surg. **25**:90-96 (Jan.) 1943.

destruction of bone, which might account for the abscesses.

He believes that the possibility cannot be entirely discarded that the apophysial arthritis observed in these patients was the result of the persistent hyperemia, which accompanied the chronic purulent infection of the paravertebral soft tissues.

[Ed. Note.—This is an interesting report, but the author's use of the term "paravertebral abscesses" is confusing. Evidently there was no roentgen evidence of an abscess next to the verterbral column, which is the usual concept of a paravertebral abscess, but the abscesses reported were in the skin and soft tissues of the neck or back. This paper seems to show, as indicated by Goldfain,[417] that ankylosing spondylitis may be caused by infection, the type of which may or may not be determined.]

Dobelle [418] presents a case of spondylitis complicating undulant fever in which spinal fusion was successfully employed and in which brucellin proved to be a most valuable adjunct. He urges early differential diagnosis in cases in which the clinical picture is similar and states that although 64 cases of spondylitis complicating undulant fever have been reported in only 3 was spinal fusion performed. Roentgenograms had shown rapidly progressive destruction of the bodies of the third and fourth lumbar vertebrae, and after fusion of an area from the third to the fifth lumbar vertebra followed by brucellin therapy subsequent films showed solid fusion and healing of the involved vertebrae.

[Ed. Note.—Evidently the fusion was of definite value in this case, in view of the progressive destruction of the vertebral bodies, but from other reports it does not seem indicated in all cases of brucellosis spondylitis. The author states, "At the time of surgery, if the posterior element involvement had been suspected, fusion would have been extended to the sacrum." This again brings up the question of whether all fusions extending down to the fifth lumbar vertebra should be extended to the sacrum. In view of the frequency of instability in the lumbosacral joint and the frequent need for fusion of this joint plus the added strain on it if the vertebrae above are fused, it seems likely that many, if not all, fusions which include the fifth lumbar vertebra should be extended to the sacrum.]

417. Goldfain, E.: Chronic Brucellosal Type of Ankylosing Spondylitis, J. Lab. & Clin. Med. **28**:1226-1231 (July) 1943.

418. Dobelle, M.: Brucella Spondylitis, Am. J. Surg. **60**:130-133 (April) 1943.

Goldfain [417] reports a study of 18 cases of ankylosing spondylitis, in 5 of which cutaneous, agglutination and opsonic index tests gave positive results for brucellosis. He points out that ankylosing spondylitis is a symptom complex and believes that the cause may be an infection which can be either determined, as in these 5 cases, or not determined in the present stage of knowledge. Chronic brucellosis, like syphilis or tuberculosis, may reveal itself in different ways, one complication being a rheumatoid type of arthritis, which when limited to the spine presents the symptom complex of ankylosing spondylitis. In 3 of the cases improvement resulted with general medical measures and bacterin therapy, in 1 the reponse was only moderately favorable and in the fifth the response to bacterin therapy was poor.

Scoliosis and Other Deformities. — Shaw [419] reviews the problems of care after thoracoplasty. He points out that the modern extrapleural thoracoplasty is an effective measure of collapse for the closure of tuberculous cavities, but most reports on the results deal with its main object, closure of the cavity and conversion of the sputum. He feels that certain sequelae of thoracoplasty must be evaluated in a full appraisal of the end results of this procedure. He discusses the chief mechanical defects of thoracoplasty that may contribute to invalidism or disability, pain in the chest or shoulder, scoliosis and limitation of motion of the shoulder. He states that pain following thoracoplasty may be constant or present only on motion of the shoulder. The constant pain is often caused by contraction of the underlying fibrotic lung or thickened pleura or to intercostal neuritis due to pinching of the nerves by the costal stumps, while pain present only on motion of the shoulder is usually due to contact of the scapula with some bony prominence.

The author discusses resection of more ribs or partial resection of the scapula for relief of pain in the scapula due to impingement of the scapula on the ribs and describes his attempt to prevent scoliosis. He states:

> Four muscles that connect the cervical vertebrae with the upper ribs have their lower attachments released at the time the first stage of the thoracoplasty is performed. These are the three scaleni and the serratus posterior superior muscle. When they are released their antagonists on the opposite side of the neck are unopposed and thus draw the head and neck to the opposite side giving the characteristic wry neck present following thoracoplasty. . . . During the past two years the author has reattached the posterior scalenus

419. Shaw, R.: Post-Thoracoplasty Care: Scoliosis, Pain and Rehabilitation, Dis. of Chest **9**:327-333 (July-Aug.) 1943.

and seratus posterior superior muscles to the sacrospinalis muscle at the time of the first stage in an attempt to partially correct this imbalance. It has not been found technically feasible to reattach the anterior and middle scaleni muscles since no supporting structure was readily available for an anchorage. It is too early to report accurate clinical results, but this procedure has promise in helping to reduce scoliosis following extrapleural thoracoplasty. It may be found that scalenotomy on the opposite side following completion of the thoracoplasty will correct severe scoliosis. To my knowledge this has not been done but it is certainly a logical procedure and deserves a trial.

The author believes that the convalescent period after thoracoplasty should be a minimum of six months.

[ED. NOTE.—This is a good review of the problem of thoracoplasty and its complications. The author's attempt to partially correct the muscle imbalance and limit the development of scoliosis by reattaching the posterior scalenus and serratus posterior superior muscles to the sacrospinalis muscle at the time of the first stage and his suggestion of scalenotomy on the opposite side to correct or prevent severe scoliosis may well be of value in certain cases. Perhaps the maintenance of proper position of the spine either straight or flexed to the side of the thoracoplasty should be stressed more in the postoperative care, especially in children. It might also be mentioned that the author does not discuss the transplantation of the lower angle of the scapula within the thoracic cage following upper thoracoplasty to obtain added compression of the lung and to overcome the difficulty of impingement of the scapula on the rib, so well described by Leahy,[420] in 1940. Leahy reports 50 cases, and I have seen a number of these operations demonstrated showing excellent results, with the patients obtaining remarkable function, even on lifting heavy objects. Leahy's excellent paper evidently has not received the attention it warrants and should be included in any review of post-thoracoplasty problems.]

Cobb[421] discusses the treatment of scoliosis and some of his observations after the study of over 2,000 cases since 1934. He gives an outline for the etiologic classification of scoliosis and one for the study and treatment of scoliosis. He lists the indications for operation and outlines the operative treatment and follow-up examination. He stresses the importance of careful study and believes that rest in recumbency is the only nonoperative treatment which seems to be of any value in arresting progressive curvatures, though this does not decrease the curve. In conclusion he states:

1. Structural scoliosis is a self-limited condition.
2. Most curvatures stop progressing spontaneously—requiring no treatment.
3. Practically all idiopathic curvatures stop progressing at or before age 15.
4. Relatively few curvatures increase to sufficient degree to require treatment.
5. Spine fusion operation is the only treatment at present which will prevent increase and maintain correction.
6. Bed rest is the only non-operative treatment which seems to arrest some progressing curves—but does not obtain improvement.
7. The main problem is in determining which cases will require operation; especially before age 15 and when the curve is increasing.
8. Indication for fusion depends on etiology, age, progress, deformity, etc.

[ED. NOTE.—It seems worth while stressing the importance of rest, especially in the treatment of idiopathic scoliosis, and the importance of careful study to avoid unnecessary operation on patients under 15 years of age when the curve is not increasing and not severe. In many patients with definite curvatures at the age of 11, 12 and 13, the curves do not increase and do not need operative correction, although this is not generally known.]

Referred Pain.—Martin[422] discusses radicular pain and its physical treatment. His review of the literature does not include the more recent articles on this subject in the past few years which have been reviewed in this survey, including that on the so-called viscerospinal syndrome. This is a good article for a general review of the subject and the medical and physical treatment, but it merely outlines the orthopedic treatment. It stresses the importance of diagnosis and also the importance of conservative treatment in many cases.

Although it is often difficult to distinguish definitely referred pains of visceral origin from those of somatic origin, there are certain characteristics of radicular pain or referred pain of somatic origin that may be of value in ruling out pain of visceral origin. 1. The history is usually not typical of any visceral disease. 2. The pain may have an indefinite localization somewhere along the distribution of the involved nerve. 3. The pain may be aggravated by motion and postural changes, by flexion of the neck or by straight leg raising. 4. The pain may be precipitated or aggravated by increased intra-abdominal and intrathoracic pressure, as in coughing, sneezing and straining. 5. There is usually an absence of deep tenderness. 6. There is usually no tenderness along the involved nerve. 7. Local tenderness may be present over the spinous processes or foramina. 8. The pain may be preceded or accompanied by paresthesia. 9. Hyperesthesia and hyperalgesia of the skin and subcutaneous tissues may be present, and hypo-esthesia and hypalgesia may develop in the later

420. Leahy: Transplantation of the Lower Scapula Within the Thoracic Cage Following Upper Thoracoplasties, Surgery **7**:875-882 (June) 1940.

421. Cobb, J. R.: Treatment of Scoliosis, Connecticut M. J. **7**:467-471 (July) 1943.

422. Martin, G. M.: Radicular Pain and Its Physical Treatment, M. Clin. North America **27**:994-1000 (July) 1943.

stages. 10. Reflexes may be diminished or absent. 11. Motor symptoms are more common than they are in visceral disease.

His summary is as follows:

Various lesions of the spinal column cause pressure on the roots of the spinal nerves. This results in radicular pain which is at times considered due to visceral disease. Correct diagnosis depends on cognizance of the radicular syndrome, careful history, physical and neurologic examinations and roentgenologic examination of the spinal column. Many of the early mechanical lesions may be treated in part by simple physical therapeutic methods while more advanced and severe lesions will require neurologic and orthopedic procedures.

[Ed. Note.—The author points out that "it is remarkable how rarely a well developed scoliosis causes radicular pain." However, he states that "in cases in which radicular pain is due to a functional scoliosis without serious organic change, and the degree of scoliosis is not severe enough to require surgical fusion, the patients also may be treated with corrective exercise." The author implies that functional scoliosis might require fusion and states: "A brace or spinal fusion may be necessary in a case of severe or rapidly progressive scoliosis that is either functional or organic." It is obvious that a spinal fusion is not necessary for functional scoliosis itself, though it may be necessary to stabilize a spine when the pain due to instability is causing functional scoliosis.]

In a study on the effects of injections of procaine hydrochloride on simulated visceral pain, Young [423] reports the results of fifty-six injections of procaine hydrochloride into the deep paravertebral muscles of 26 patients with spondylitis. All these patients had simulated visceral pain, and the symptoms could be reproduced by pressure on the muscles lateral to one or more vertebrae and by torsion or hyperextension of the spine at the same level. They were divided into two groups, those with and those without visceral disease, and in both groups the results were uniformly good. The author believes that these were probably due to the dissolution of a vicious reflex cycle, though he points out that a complete explanation of the prolonged therapeutic results cannot be offered. He feels that this method has been so effective, so simple and so free from complications that its continued use is indicated.

Posture.—In a physiologic study of the vertical stance of man, Hellebrandt and Franseen [424] give a review of the literature, with three hundred and seven references, and discuss thoroughly the physiologic factors in posture.

They point out that the evolution of the biped stance has been marked by a narrowing of the base of support and a progressive elevation of the center of gravity of the body as a whole. Both militate against stability. They stress the point that "the vertical posture also imposes an hydrostatic handicap which encroaches enough on the adequacy of the circulation to make man in the upright stance vulnerable to peripheral circulatory collapse." They feel that the numerous difficulties seemingly attributable to a change from quadruped to biped standing, which are interpreted by some as signs of extreme inadequacy of adaptation, are counteracted easily in the majority of normal men by compensatory mechanisms, which automatically cancel the apparent mechanical disadvantages of the change.

They point out:

The relative importance of vasoconstriction, cardiac acceleration, augmentation of respiration, skeletal muscle tone, and insensible contraction, to the maintenance of an adequate circulation during standing in man, has not been determined.

They feel that it has yet to be shown that posture is a decisive etiologic factor in the failures in adaptation to vertical stance, which occasionally are so acute as to cause syndromes of pathologic significance.

[Ed. Note.—This is an excellent article, which should be read by those interested in posture, as it cannot be adequately summarized. It has a complete bibliography on the subject.]

Fries and Hellebrandt,[425] in studying the influence of pregnancy on location of the center of gravity, postural stability and alinement of the body, point out that aside from studies made on changes in weight and alterations in the pelvic joints few, if any, consecutive observations have been reported on the readjustments of the parts of the body as they accrue in pregnancy and regress during puerperium. They recorded postural adjustments of the pregnant woman by means of serial biplane photographs synchronized with observations on the center of gravity and report an almost exact return to the original values of three factors: body weight, height of the center of gravity and eccentricity of stance.

In the 2 subjects studied there appeared to be an unexpected slight change in the lumbar region of the spine, the "exaggerated lumbar curve," which is commonly thought to occur, not being prominent. The curves in both sub-

423. Young, D.: The Effects of Novocain Injections on Simulated Visceral Pain, Ann. Int. Med. **19**:749-756 (Nov.) 1943.

424. Hellebrandt, F. A., and Franseen, E. B.: Physiological Study of the Vertical Stance of Man, Physiol. Rev. **23**:220-255 (July) 1943.

425. Fries, E. C., and Hellebrandt, F. A.: The Influence of Pregnancy on the Location of the Center of Gravity, Postural Stability, and Body Alinement, Am. J. Obst. & Gynec. **46**:374-380 (Sept.) 1943.

jects appeared almost parallel. They believe that the data indicate that the major counterbalancing adjustments are made by elevating the head, extending the cervical portion of the spine, stabilizing the knee joint and leaning backward from the ankle.

[ED. NOTE.—This is an interesting study but is based on only 2 subjects and may not represent the findings in a larger series. Also there may be more definite changes in the vertebrae than would be suspected from the photographs, and lateral roentgenograms might show more of a change, especially in the lumbar area. It is well known that in cases of scoliosis subsequent photographs or silhouettes may show improved posture, but the roentgenograms may show a decided increase in the curve, which is not detected in the photograph.]

Fractures and Dislocations.—Dingman [426] describes a new splint for cervical fractures and dislocations, with illustrations to demonstrate its construction and use and roentgenograms to show the reduction obtained in 1 case in which this splint was used. The splint was devised primarily to insure the same transportation of patients with fractures and dislocations of the neck, and the author states that it "combines the principles of traction, extension and immobilization." The advantages of the splint are that the amount of traction can easily be measured with an ordinary scale, unobstructed anteroposterior and lateral roentgenograms can be taken and the countertraction pushing down on the shoulders simplifies visualization of the seventh cervical vertebra.

[ED. NOTE.—I have seen this ingenious splint demonstrated, and it seems to solve many of the problems of transportation and care in the difficult cases. While traction on the skull will probably still be necessary for adequate reduction in some cases, application of this splint will probably be adequate treatment in many of them. It probably could be used with skeletal traction also.]

Hook and Mazet [427] review the different methods of treatment of fractures of the cervical portion of the spine and favor the use of skeletal traction with Crutchfield tongs. To make the patients ambulatory with the tongs in place, especially if evacuation is necessary, they devised an ambulatory traction apparatus. It consists of a steel strap and is incorporated in a plaster jacket. The steel strap extends up over the head, with several holes in the top end so that the tongs can be secured to it. To take up the slack incident to variations in tension produced by changes in position, they inserted a coil spring between the strap and the tongs. They found that it was important to extend the jacket up on the neck posteriorly as high as possible and over the shoulders to secure firm fixation of the bar. The steel strap must be strong and not too springy.

The authors present 2 cases in which this method of treatment was used. While they do not advocate it as a routine method of treatment, they feel that it has a place for patients for whom evacuation is necessary and reduction cannot be maintained in a plaster collar or for elderly or plethoric persons for whom prolonged recumbency is contraindicated.

[ED. NOTE.—This is an interesting method of treating fractures of the cervical portion of the spine and will probably be of definite value in selected cases.]

Lyon [428] presents a case of so-called backward displacement of thoracic and lumbar vertebrae, with a discussion of the causes, age factor and treatment and of the mechanism of backward displacement of one vertebra on another. He states:

> The exciting cause of backward displacement is seen in dorsoventral tears and fissures of the intervertebral disk situated below the shifted vertebrae, which causes loosening of the structure of the disk. Attention is directed to the prominent part played by the posterior longitudinal ligament, the participation of which has not been given much consideration up to the present. It is not until this ligament yields its pressure that a vertebra can be thrown backwards.

[ED. NOTE.—While the author may be correct in his explanation, the case presented certainly does not prove his point. The roentgenograms show wedging of the twelfth dorsal vertebra, some osteoporosis but no evidence of real backward displacement. They demonstrate compression of the twelfth dorsal vertebra with compensatory backward tilting of the vertebrae below.]

Davis,[429] in a paper on new aspects of spinal injuries, records points concerning the treatment of spinal injuries on which general agreement has been reached, points on which there still exists considerable divergence of opinion and a number of new aspects which may be considered addenda to the general subject of spinal injuries.

426. Dingman, P. V. C.: A Splint for Cervical Fractures and Dislocations, J. Bone & Joint Surg. **25**: 473-476 (April) 1943.

427. Hook, F. R., and Mazet, R., Jr.: An Ambulatory Traction Device for Treatment of Fractures of Cervical Spine, U. S. Nav. M. Bull. **41**:207-213 (Jan.) 1943.

428. Lyon, E.: Backward Displacement of Thoracic and Lumbar Vertebrae, J. Internat. Coll. Surgeons **6**: 490-495 (Sept.-Oct.) 1943.

429. Davis, A. G.: New Aspects of Spinal Injuries, Arch. Surg. **46**:619-634 (May) 1943.

The author stresses the importance of careful study to discover any cracks or dislocations of a posterior vertebral arch, pointing out that wherever a double shadow of a vertebra appears dislocation of one articular process must be expected and that oblique roentgenograms taken at an angle of 30 to 40 degrees are more likely to exhibit fracture lines in the articular processes than lateral roentgenograms.

[Ed. Note.—This is an excellent article and stresses the importance of involvement of the posterior elements in spinal injuries, which still seems to be not generally appreciated.]

Lesions of Disks.—Stump and Narins [430] report a case of injury to an intervertebral disk during spinal puncture in a 12 year old girl with meningitis. Roentgenograms taken after the puncture showed collapse of the disk between the third and the fourth lumbar vertebra. Subsequent films showed a further thinning of the disk with increased opacity of the lower portion of the third lumbar body and the upper portion of the fourth lumbar body, which was considered indicative of an inflammatory process. They believe that in this case an inflammatory process developed after the penetration and perhaps after the direct inoculation of the disk with a needle for spinal tap.

[Ed. Note.—While injuries to the intervertebral disk during spinal puncture have been previously reported and reviewed in this survey, it is perhaps well to stress this as a complication which is being noted more frequently.]

Bucy and Speigel [431] report an unusual complication of the intraspinal use of iodized oil. The patient had had a spinal fusion in the lumbosacral area in April 1937 and an intraspinal injection of iodized oil in March 1938, after which fluoroscopy revealed some of the oil lodged at the level of the eighth thoracic vertebra. Progressive symptoms of involvement of the spinal cord developed at that level. In February 1942 lumbar puncture revealed an almost complete spinal block. At operation two collections of encysted iodized oil in the subarachnoid space and a thickened arachnoid membrane were found and removed. They believe that this patient had localized adhesive arachnoiditis at the level of the eighth thoracic vertebra prior to the injection, which caught and held some of the oil.

[Ed. Note.—This is another example of encysted iodized oil after injection for localization of spinal lesions. It should be another warning against the use of iodized oil and stresses the importance of removing the oil either by aspiration or by operation. Evidently more and more orthopedic surgeons are finding fewer indications for the intraspinal injection of iodized oil, and many do not even use it for the usual suspected lesions of disks. Many feel that in most cases the lesions can usually be adequately localized clinically or by roentgen rays without the use of intraspinally injected contrast mediums.]

In an excellent article on intraspinal administration of colloidal thorium dioxide Nosik [432] briefly reviews the literature on the use of this material and in a short and concise outline gives the method of preparation, the technic for making the myelogram and the treatment after myelography. He also discusses the advantages and disadvantages of intraspinally injected contrast mediums and the advantages of thorium dioxide. He reports 100 cases and states:

> In the positive myelograms confirmed by operation the diagnostic accuracy of thorotrast is 93.97 per cent (error of 6.17 per cent). In the negative myelograms which were explored on clinical grounds alone, the diagnostic accuracy of thorotrast was 89.97 per cent, the error 11.1 per cent.

The author's conclusions are as follows:

> The search for the ideal intraspinal contrast medium is not ended. By instituting the technique described here, we have eliminated most of the undesirable features of thorotrast. A medium has not yet been found which will outline every structure within the subarachnoid space, sharply define its every ramification, and then be spontaneously absorbed and eliminated after it has served its purpose.

[Ed. Note.—Any one wishing to use colloidal thorium dioxide with this method will find this article of great value.]

Oppenheimer [433] discusses the pathologic features, the clinical manifestations and the treatment of lesions of the intervertebral disks. On the basis of a series of 826 cases of lesions of disks observed during the last eight years, of a control series of 200 cases in which no symptoms existed and of another control series of 100 cases in which there were symptoms suggestive of lesions of disks, he attempts to ascertain whether correlations can be established between the clinical and the anatomic findings and whether principles can be defined by which treatment may be directed. The author discusses the pathologic features, dividing the common lesions into those caused by rupture and those due to degeneration.

430. Stump, J. P., and Narins, S. A.: Intervertebral Disc Injury During Spinal Puncture, U. S. Nav. M. Bull. **41**:400-403 (March) 1943.

431. Bucy, P. C., and Speigel, I. J.: An Unusual Complication of the Intraspinal Use of Iodized Oil, J. A. M. A. **122**:367-369 (June 5) 1943.

432. Nosik, W.: Intraspinal Thorotrast, Am. J. Roentgenol. **49**:214-218 (Feb.) 1943.

433. Oppenheimer, A.: Development, Clinical Manifestations and Treatment of Rheumatoid Arthritis of Apophyseal Intervertebral Joints, Am. J. Roentgenol. **49**:49-76 (Jan.) 1943.

He found:

The incidence and severity of the clinical manifestations were not proportional to the degree of disc thinning, as measured by the width of the intervertebral space. No correlation could be established between any of the clinical signs and symptoms, on the one hand, and the degree of disc thinning on the other.

The author also states:

. . . that lesions of the discs cause symptoms felt in the periphery rather than in the spine and that, in the presence of disease of the spine, pain and rigidity of vertebral regions are caused in most cases by involvement of the apophyseal joints. Since disc lesions induce arthritis of the apophyseal joints in only about one fifth of the cases, symptoms felt in the spine are not common, and the vertebral origin of peripheral pain easily escapes recognition.

He believes that such signs as pain in the back induced by sneezing and coughing are certainly not typical of rupture of a disk and may be observed in the presence of various other lesions of the vertebrae. He found that clinical signs suggestive of lesions of disks were due to some other disease in about 10 per cent of the cases and that their connection with a demonstrable lesion of a disk was questionable in at least another third, so that roentgenographic demonstration of a diseased disk does not prove the discogenic origin of the symptom, and in about two thirds of the cases certain clinical manifestations were probably due to lesions shown roentgenographically.

For treatment the author favors positions and exercises to relieve pain but has been dissatisfied with the use of braces and traction. In 582 cases roentgen ray therapy was used for the control of backache and radicular nerve pain, and, although many authors believe its effects are highly questionable, he believes that the value of this mode of treatment is not generally recognized. The best results of roentgen ray therapy were noted for patients with trophic disturbances of the skin, muscles and bones in the peripheral segments corresponding to the involved disk, and he reports the disappearance of severe lesions within a number of weeks.

In conclusion, the author states that no matter what is the cause of the injury and degeneration flattening of the disk leads to narrowing of the corresponding intervertebral spaces, associated with displacement of articular processes, narrowing of the neural foramen and abnormal contact between vertebral bodies and that the clinical manifestations depend on these secondary alterations rather than on the degree of thinning of the disk. He believes:

The signs and symptoms of radicular neuralgia and neuritis are often indistinguishable from those of myalgia, peripheral arthritis, bursitis and pain referred from diseased viscera. Moreover, in the age group in which the incidence of disc lesions is highest, involvement of joints, bursas and viscera is also common. The difficulties encountered in recognizing disc lesions are chiefly caused by these diagnostic limitations. When disc lesions coexist with other diseases that are known to induce peripheral pain, the differential diagnosis can be made only after exhaustive clinical studies are made.

The author reports satisfactory results with conservative treatment in 75 per cent of the cases.

[ED. NOTE.—It seems desirable to stress the importance of adequate studies in all cases of pain in the back, neuritis, sciatica, etc., especially to rule out the possibility of diseased viscera and other nonorthopedic problems. There is a tendency for many physicians, including orthopedic surgeons, to rely on inadequate histories, incomplete physical examinations and too few consultations with other specialists and resort to routine treatment consisting of physical therapy, supports or operation, when the major lesion may be nonorthopedic. Apparently it is not uncommon for the busy orthopedic surgeon to overlook the general medical picture and treat the patient orthopedically for pain in the back due to some visceral lesion, such as a gastrointestinal malignant growth.]

(To Be Continued)